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THE SOLAR SYSTEM'S HIDDEN WONDERS p. 58

HOW TO FIND ET WITH INFRARED LIGHT p. 30

JUNE 2013

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SPECIAL REPORT

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BY DAVID J. EICHER

Waiting on Comet ISON

The appearance of a bright comet in Earth's skies is one of the most exciting astronomical events of all. Whenever a really bright comet appears, chatter rises, attendance at star parties zooms, circulations of astronomy magazines climb, and new blood enters the hobby of astronomy.

It's happened that way time after time since astronomy became an organized hobby, most recently with the great comets Ikeya-Seki (1965), West (1975/6), Halley (1985/6), Hyakutake (1996), and Hale-Bopp (1996/7). More than 15 years have passed since the last bright comet graced the skies of the Northern Hemisphere. But the time may have come.

My friend David Levy, one of history's most successful comet hunters, has a favorite saying: "Comets are like cats. They have tails, and they do precisely what they want." This underscores one of the great challenges with comets — their lack of predictability. The latest go-around began in September 2012, when astronomers discovered a potentially bright comet that could dazzle observers the world over this fall.

On September 21, 2012, astronomers Vitali Nevski from Vitebsk, Belarus, and Artyom Novichonok of Kondopoga, Russia, captured images of a new object in the sky. Their instrument of choice was the 16-inch Santel reflector at Kislovodsk Observatory in Russia, along with a program of automated asteroid detection called CoLiTec. The telescope is one of 18 the Russian Academy of Science has dedicated to detecting and tracking faint objects in the sky; the network is collectively termed the International Scientific Optical Network (ISON).

When the Russians announced a suspected comet, astronomers at the Mount Lemmon Survey in Tucson, Arizona, part of the Catalina Sky Survey, and others at the Pan-STARRS telescope in Hawaii checked earlier images and also found the object. The next night, more observations were made by Italian astronomers at the Remanzacco Observatory, using another network, this one called iTelescope. The Minor Planet Center in Cambridge, Massachusetts, the clearinghouse for such astronomical discoveries, proclaimed the new comet September 24, 2012, three days after its discovery.

After other astronomers verified it, the new object, as with all comets, received a designation, C/2012 S1, and its popular name matched not one of the discoverers, but, following international agreements, the search network abbreviation. So C/2012 S1 (ISON) was born.

ISON is exciting to astronomers because of its potential as a sungrazer — a comet that will sweep in very close to the Sun and therefore brighten dramatically. At perihelion, its closest approach, the comet will pass a mere 1.1 million miles (1.8 million kilometers) from the Sun's "surface." When this happens November 28/29, 2013, the comet could be dramatically bright. But that will take place in a daytime sky, when the comet is only 1.3° northeast of the Sun.

Fortunately, the comet should be dazzling in a nighttime sky as well — to be more precise, in the early morning sky in mid-November. The comet could then shine as bright as the planet Venus and become the brightest comet ever seen by anyone now alive.

Yours truly,

David J. Eicher
Editor

Astronomy

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JUNE 2013

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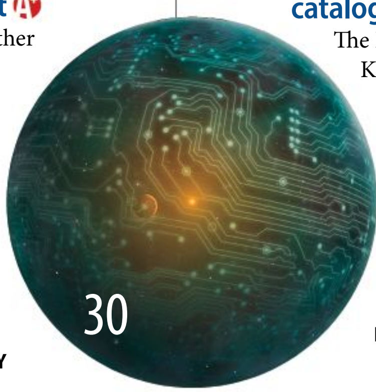
RON MILLER FOR ASTRONOMY

ON THE COVER

A small asteroid slammed into Earth's atmosphere above Russia on February 15, creating the biggest fireball seen in a century.

FEATURES



COLUMNS

QUANTUM GRAVITY

IN EVERY ISSUE

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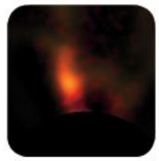
QG QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES >>

TRENDING TO THE TOP

H_2O ON THE MOON
Scientists detected water in the Apollo mission lunar samples. Thus, they say online February 17 in *Nature Geoscience*, the early Moon was wet.



FORMING PLANET?
Scientists directly imaged a possible protoplanet still forming within host star HD 100546's dusty disk. If confirmed, it would be the first such discovery.

COOL ARRAY
On March 13, the Atacama Large Millimeter/sub-millimeter Array team inaugurated the Chilean observatory by linking all 66 antennas together.

SNAPSHOT

A brief appreciation of galaxies

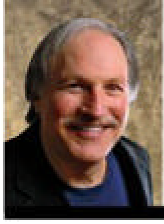
Bright, faint, big, or small, galaxies are islands in a cosmic sea.

Galaxies are everywhere in the universe. More than 10,000 are visible in a single picture taken a few years ago — the Hubble Ultra Deep Field, which shows a small piece of sky in the constellation Fornax. A small telescope reveals hundreds of galaxies strewn across the sky. And with recent research using ground-based and orbiting telescopes, astronomers now estimate some 125 billion galaxies lie scattered across the cosmos.

Galaxies are the basic large-scale building blocks of the universe. Vast collections of stars, gas, and dust, they also contain weird objects such as the black holes that inhabit most galaxies' centers. Like different models of houses, these star cities exist in a vast array of shapes, sizes, and structures. Bound by gravity that keeps their contents together, galaxies offer astronomers endless research. The next time you're out under the stars, take a look at some galaxies. They show us the nearly infinite variety of the universe.
— David J. Eicher

The Pinwheel Galaxy (M33) in Triangulum offers backyard observers a stunning sight.

TONY HALLAS (PINWHEEL GALAXY); NASA/JOHNSON SPACE CENTER (H_2O ON THE MOON); ESO (FORMING PLANET?); ALMA (ESO/NAOJ/NRAO)/J. GUARDA (ALMA) (COOL ARRAY)



STRANGEUNIVERSE
BY BOB BERMAN

Travel to the stars

The inside story on astro-tourism.

Would you travel to get a better view of the universe? While most live amid light pollution, many take vacations in rural destinations. Bingo: celestial splendor.

In addition, increasing numbers of nature enthusiasts journey to far-flung places for celestial events like aurorae and total eclipses. The growing astro-tour industry is therefore long overdue as a topic for this page. And you may enjoy hearing the "inside story," even if the subject is self-serving.

This magazine works with MWT Associates, an excellent science tour company. Before 2006, *Astronomy* used other enterprises, including Specialty Tours, led by George Scheitinger. I've lectured for both outfits, and the latter recently created a subsidiary called Berman Astronomy Tours. You can't go wrong with either one.

With Scheitinger, my tour groups have seen seven total eclipses and countless auroral displays. We have our secret destinations and usually return to them. But a few months ago, Scheitinger asked if I could think of some novel tours beyond the usual eclipse and aurora expeditions.

Travel companies have done this before. MWT Associates hit upon the idea of taking people to the Sahara Desert to look for meteorites, their most recent such trip occurring in 2011. And in 1996, another company hired comet co-discoverer Tom Bopp, the late comet expert Fred Whipple, and me to conduct a cruise when Comet Hale-Bopp first became visible.

That excursion was totally unnecessary. The comet would be just as visible from Nebraska. But who'd object to sailing the warm Caribbean in March? Everyone loved it.

So, creating new itineraries is now the rage. With this as background, it suddenly hit me that this coming November, the greatest comet of our lives may materialize. Comet ISON should be wonderful from the rural U.S., albeit very low, so why not catch it *before* perihelion, when it's higher up and guaranteed to be in one piece, prior to its perilously close encounter with the Sun?

But where to go? I've spent five years overseas in 44 countries, so I have definite ideas about what would make a great astronomy tour. I also have biases. I'm not a gambler, so I eliminate casino resorts — and, anyway, we want dark skies. I'm also turned off by rows of high-rise buildings. I hate cockroaches, too, so forget places like Rio. Meanwhile, friendly people make a trip memorable, and some lands are renowned for their warmth.

THE COMET WOULD BE JUST AS VISIBLE FROM NEBRASKA. BUT WHO'D OBJECT TO SAILING THE WARM CARIBBEAN IN MARCH?

Unique natural scenery is important, and clear skies are vital. Berman Astronomy Tours took a group to New Zealand last November, and the South Island was gorgeous. But it was cloudy most of the time. I should have checked the climate stats ahead of the tour.

So now, thinking about the upcoming comet, northern Chile sprang to mind. It's a favorite place of mine. The Atacama Desert is the driest on Earth as well as visually stunning and safe. The nearby Andes are breathtaking. I also have a personal connection with a fabulous private observatory in the area, where the skies are beyond belief, that would let us feel as if we're in space. There's nothing like it.

So in January, some of us at Berman Astronomy Tours traveled south to do recon for the trip — my first time participating in such a task. I gaped at the blood-red star DY Crucis through the observatory's 0.5-meter telescope. The Magellanic Clouds were so brilliant that you almost needed sunglasses. The Milky Way cast shadows. What a contrast from, say, Beijing, where not a single star is visible to skywatchers.

We decided to house the Comet ISON tour group in green Andean valleys, bus the travelers to the observatory and desert by night, and do side trips like seeing penguin and dolphin colonies in the cold Humboldt waters alongside the desert. And then we set up charter coaches; found cool, quaint hotels; scoped out restaurants; and drove various desert routes until we were happy with the whole itinerary.

To investigate a four-day "extension" afterward, which most people enjoy as an option, we then flew to Peru to check out the Cuzco/Machu Picchu tour. We set that up in a day, and then had time to ponder other options. Inland southern Peru, where the tourists go, is often cloudy, but what about the desert-like north? A Peace Corps friend generously showed me that less-traveled region.

You've got to salute those Peace Corps altruists. Paid just $400 a month, out of which they arrange rent and everything else, they eat rice and potatoes most of the time. They live in tiny mudrooms. When we visited my friend's "family," a rat was running over his bed.

At night, giant roaches occupied the kitchen. Fly season had just begun, so they were everywhere, too. Plus, Peruvians love setting off ear-splitting cherry bombs with a strange regularity. They also have the odd custom of locking dogs on the roof, where they bark down at you.

We scratched that region off the "possible tour" list.

It was a small, odd "inside glimpse" at the astro-tourism business.

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

Happily surprised by a lunar alignment

On most evenings, my wife and I periodically go outside, face south, and look to the heavens. We like to see what's happening in the sky.

We kept going out to look again and noticed that the Moon was pulling away from Jupiter, and by 10:20, the planet was outside that coronal ring. We had quite a remarkable evening of "star" gazing. The next morning, I looked in *Astronomy* to find that Jupiter was only 0.4° from the Moon on December 25 at 7 P.M. EST. We really lucked out, thanks to the cosmos! — **John Mood,** San Diego

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

Up in arms

Four distinct arms spiral out from the center of M106, a galaxy that lies some 24 million light-years from Earth in Canes Venatici. Two of the arms look normal, with bright blue star clusters and reddish stellar nurseries entwined with dark dust lanes. But the other two reddish "anomalous arms" consist entirely of glowing hydrogen gas heated by energy produced near the supermassive black hole that lurks at M106's center. Astroimager Robert Gendler created this portrait by combining archived Hubble Space Telescope images with photos he and fellow imager R. Jay GaBany captured from dark sites in New Mexico. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)/R. GENDLER (FOR THE HERITAGE TEAM)

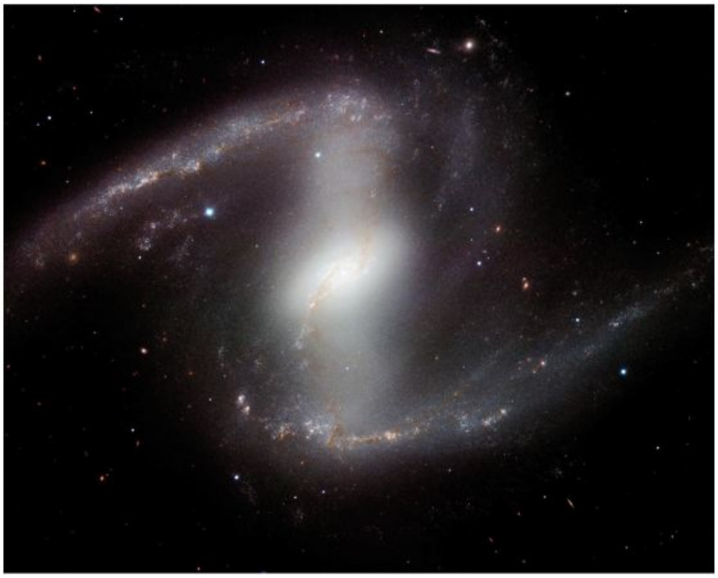
SALMONELLA IN SPACE. Microbiologists described on February 18 their research about the effects of microgravity on disease-causing organisms; they performed these experiments aboard the International Space Station.

BLACK HOLE'S SPIN MEASURED

Just three quantities describe a black hole: its mass, charge, and spin. While astronomers can calculate the mass through basic laws of physics, measuring a black hole's charge and rotation is more difficult. Now, a team of astronomers has measured a supermassive black hole's rapid spin for the first time; the study appeared in the February 28 issue of *Nature*.

Guido Risaliti of the Harvard-Smithsonian Center for Astrophysics and colleagues studied the X-ray emission from the supermassive black hole at the center of NGC 1365 using the Nuclear Spectroscopic Telescope Array (NuSTAR). When analyzing the 130,000-second observation, the astronomers found variability on few-hour timescales.

From that X-ray spectrum, the team learned that the 2-million-solar-mass black hole spins at no less than 84 percent the speed of light.



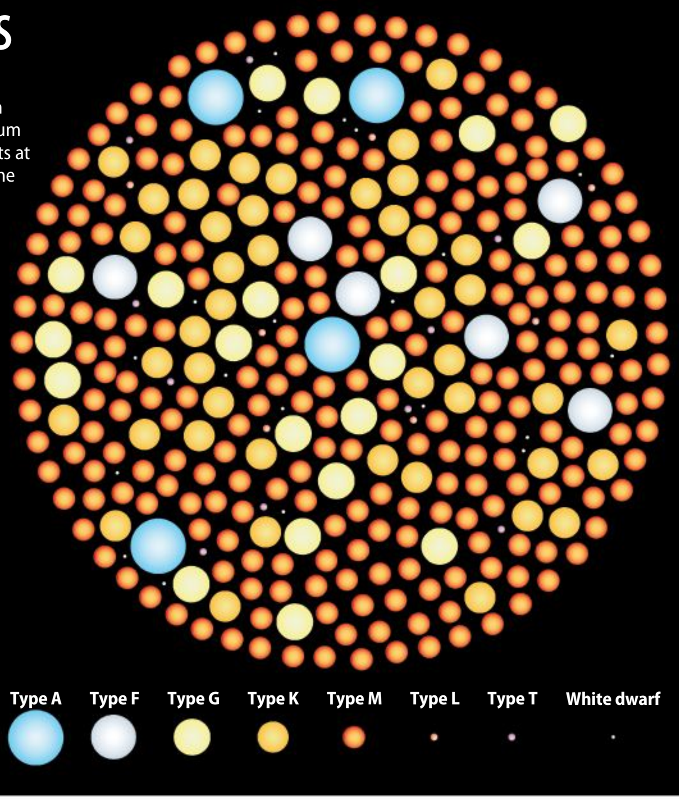
SPEEDY SPIN. By studying high-energy X-rays, astronomers learned that the supermassive black hole at the center of barred spiral galaxy NGC 1365 rotates at no less than 84 percent the speed of light. ESO/P. GROSBØL

The spin rate provides hints about how the supermassive black hole grew. A black hole will acquire the rotational momentum of infalling matter it devours; if many small clumps of gas fed the monster, then the spin would be randomized and essentially smoothed out — and thus much slower. But the high spin rate of NGC 1365's central black hole implies that the behemoth grew through either one main event of infalling material or a few smaller ones. — **Liz Kruesi**

THE NEAREST STARS

STELLAR NEIGHBORHOOD. Within 32.6 light-years of the Sun sit 358 stars and brown dwarfs. Todd Henry of the Research Consortium On Nearby Stars releases a list of these objects at the beginning of each calendar year. Here's the updated census for 2013, shown visually.

ASTRONOMY: LIZ KRUESI AND ROEN KELLY



FAST FACT

On March 12, Penn State University astronomer Kevin Luhman announced his discovery of a star system 6.5 light-years away, the closest found to the Sun since 1916. The binary, uncovered in data from NASA's Wide-field Infrared Survey Explorer, consists of two brown dwarfs.

QUICK TAKES

MARTIAN MAVEN
On February 8, NASA officials announced that the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft completed assembly and began environmental testing. The mission is scheduled for a November 2013 launch.

FEEBLE FEEDING
Some black holes grow faster than galaxy-collision material can feed them, say astronomers in a March 1 study published in *The Astrophysical Journal*.

A NEW NAME
The Kielder Observatory Astronomical Society and the BBC's *The Sky at Night* renamed the facility housing a 20-inch telescope at the Kielder Observatory in England The Sir Patrick Moore Observatory in honor of the late astronomy popularizer.

ET INTELLIGENCE
A study in a future issue of *The Astrophysical Journal* will describe how researchers studied radio emission from 86 candidate planetary systems to calculate that fewer than one in a million stars in our galaxy hosts an intelligent civilization.

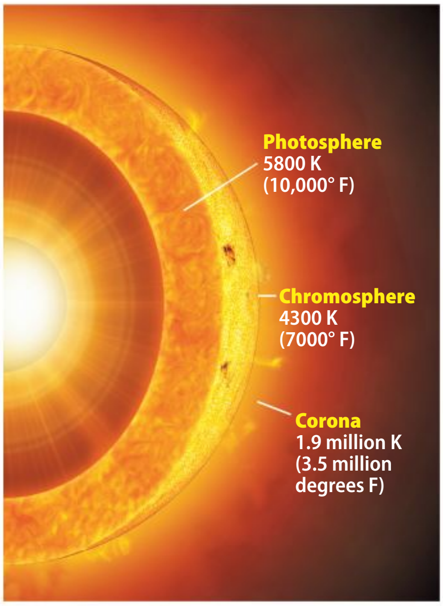
WHIRLING ROCK
Radio astronomers studied the spin of asteroid 2012 DA_{14} as it passed near Earth on February 15 to help predict its future trajectory.

TINY TELESCOPES
The twin BRIght Target Explorers (BRITE) launched February 25. The smallest space telescopes yet deployed, each less than 15 pounds (7 kilograms), BRITE will study luminosity variations in stars.

ASTEROID FINDER
On February 15, the University of Hawaii announced that a recent $5 million grant from NASA will help develop the Asteroid Terrestrial-Impact Last Alert System.

BALLOON BREAKING
The Super-TIGER cosmic-ray balloon experiment returned to Earth on February 1 after remaining aloft above Antarctica for 55 days, 1 hour, and 34 minutes, smashing the previous record. — **L. K.**

KRUESI KUDOS. On February 28, *Astronomy* Associate Editor Liz Kruesi won the 2013 David N. Schramm Award for High Energy Astrophysics Science Journalism for her April 2012 article "How we know black holes exist."



COOL CHROMOSPHERE. Astronomers have discovered a relatively cool layer in the lower atmosphere of nearby "solar twin" Alpha Centauri A, the first measurement of such a temperature minimum in a star other than the Sun. *ASTRONOMY*: ROEN KELLY

"Solar twin" has cool atmospheric layer, too

The nearby star Alpha Centauri A is often called the Sun's twin because the two have similar masses, temperatures, chemical compositions, and ages. Because of these connections, scientists like to study the sun 4.37 light-years away to better understand characteristics of our home star — to see if attributes they discover about our Sun exist elsewhere.

One such curiosity about our star is that its visible surface, called the photosphere, is about 5800 kelvin (10,000° Fahrenheit) while its outer atmosphere, called the corona, can spike to as hot as 1.9 million K (3.5 million degrees F). And then there's a temperature minimum of about 4300 K (7000° F) between the two layers in the chromosphere. Alpha Centauri A also has a significant temperature difference between its photosphere and corona, so astronomers set out to see if the nearby star has the unexpected temperature minimum as well.

Using the European Space Agency's Herschel Space Observatory, scientists for the first time observed this cool layer in a star beyond the Sun, as reported in the January *Astronomy & Astrophysics*. "The study of these structures has been limited to the Sun until now, but we can clearly see the signature of a similar temperature inversion layer in Alpha Centauri A," says lead author René Liseau of the Onsala Space Observatory in Sweden. "Detailed observations of this kind for a variety of stars might help us decipher the origin of such layers and the overall atmospheric heating puzzle." **— Karri Ferron**

SPACE SCIENCE UPDATE

NATURE'S ACCELERATOR. IC 443 is one of the supernova remnants that accelerate protons to the extreme energies of cosmic rays. This multiwavelength image incorporates gamma-ray (pink), optical (yellow), and radio data. GAMMA RAYS: NASA/DOE/FERMI LAT COLLABORATION; OPTICAL: TOM BASH AND JOHN FOX/ADAM BLOCK/NOAO/AURA/NSF; INFRARED: JPL-CALTECH/UCLA

LINK BETWEEN SUPERNOVA REMNANTS AND COSMIC RAYS CONFIRMED

Cosmic rays — extremely high-energy particles from space — were first discovered in 1912. Over time, scientists have found that some 90 percent of those particles are protons while the remaining 10 percent are electrons and other atomic nuclei. But they lacked direct evidence of the process that accelerates these particles to such extreme energies. Now, a study published in the February 15 issue of *Science* describes the responsible mechanism.

A cosmic ray has either a positive or negative charge, and thus its trajectory changes as it traverses the Milky Way's magnetic fields. As cosmic rays collide with diffuse gas in the galaxy, they can produce high-energy gamma rays along with other particles. Gamma rays have no electric charge, so magnetic fields don't affect them.

A cosmic-ray proton colliding with another proton in interstellar gas creates a particle called a neutral pion in addition to other products. That pion then decays into two gamma rays that have a specific energy signature. So, if scientists could find a location where gamma rays of that energy are created, they could determine where cosmic rays originate.

An analysis of four years of data from the Fermi Gamma-ray Space Telescope did just that. Stefan Funk of Stanford University and colleagues studied the gamma-ray signature of two supernova remnants — IC 443 and W44 — and found the characteristic energy signature that results from the decay of neutral pions, and thus from high-energy protons slamming into lower-energy ones.

The Fermi results prove a theory of cosmic-ray acceleration first suggested by physicist Enrico Fermi in 1949. At the front of a supernova's quickly expanding gaseous shell is a shock wave. This shock possesses a strong magnetic field. As a proton crosses that magnetic region, its energy increases by about 1 percent of its original intensity. A small number of protons will traverse the shock front hundreds of times, boosting their energies and speeds. Occasionally, they will break free from the remnant and travel across the galaxy.

While the two supernova remnants that Funk's team studied arose from the death of massive stars, type Ia supernovae (white dwarfs that explode once they collect enough material from their companions) also could contribute to cosmic-ray acceleration. "All you need from the supernova is ejecta moving through the interstellar material faster than the surrounding material, i.e., all you need is an explosion," explains Funk.

According to the researchers, the next step is to determine the details of the acceleration mechanism and the maximum energy that accelerated cosmic-ray protons can attain. **— L. K.**

FAST FACT

NASA's Spitzer and Hubble telescopes detected an infant star that behaves like a strobe light, emitting a burst of radiation every 25.43 days.

BRIEFCASE

QUESTIONING EINSTEIN

Stars in faint dwarf galaxies surrounding the Andromeda Galaxy (M31) move (almost) exactly as fast relative to each other as MOdified Newtonian Dynamics (MOND) predicts they should, according to a paper forthcoming in *The Astrophysical Journal*. MOND, an alternative to dark matter as an explanation for galaxies' fast rotation rates, suggests that the law of gravity needs tweaking under certain conditions. — **Sarah Scoles**

●

BORING ON MARS

NASA's Curiosity continues to make history. On February 20, NASA announced that the robot had drilled into its first rock, leaving a 2.5-inch (6.4 centimeters) hole in the Red Planet, to become the first rover to collect a sample from an extraterrestrial object's interior. — **S. S.**

●

STELLAR OUTLIERS

Astronomers used Hubble Space Telescope data to discover a shell of stars around the Milky Way. Their sideways motion suggests they came from somewhere else — from a group of stars traveling and rotating differently from the Milky Way — and a paper forthcoming in *The Astrophysical Journal* says they once belonged to a small satellite galaxy that our spiral devoured. — **S. S.**

25 years ago in *Astronomy*

In the June 1988 issue of *Astronomy*, Jeff Kanipe wrote about the hunt for the most distant quasars — those that formed as quickly as dark matter would allow after the Big Bang.

In his article "Quest for the most distant objects in the universe," Kanipe described the state of the search for primeval galaxies. In these structures, stars are turning on for the first time in the history of the universe. When the article was written, the most distant known galaxy was 12 billion light-years away. The current record-holder is almost 1 billion light-years more distant.

10 years ago in *Astronomy*

In the June 2003 issue of *Astronomy*, Paul Spudis penned "Harvest the Moon" about the future of human spaceflight. He said the trip would be beneficial scientifically, politically, and economically — and that if NASA wanted a new goal, Earth's closest satellite was the place to set its sights.

"The urge to explore beyond familiar horizons is one of humanity's greatest drives," he said. "We need a new challenge in space. It must be difficult yet achievable, substantial yet manageable." NASA and private industry continue to work toward that goal today. — **S. S.**

OBSERVING**BASICS**

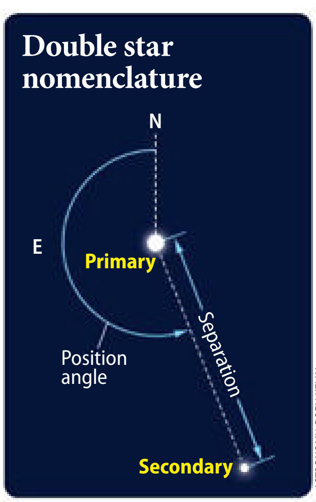
BY GLENN CHAPLE

Double star fever

The beauty of these summer stellar pairs might lead to a new passion.

I suffer from a severe case of double star fever, having caught the bug in the early 1960s when a high school friend showed me Mizar (Zeta [ζ] Ursae Majoris) through a small reflecting telescope. Before long, I had purchased a telescope of my own and began observing double and multiple stars with relentless abandon. A half-century later, I still ply the night sky with a telescope, chasing down cosmic gem sets that have thus far eluded my eye.

Catalog data for a double star include three elements: the magnitudes of the components, their separation in arcseconds, and the position angle (location of the fainter, or secondary, star relative to the primary). The magnitudes and separation tell us whether a double star is easy or difficult to resolve. Wide pairs are easier to split than close ones; double stars that consist of equally bright partners are better resolved than those whose members differ greatly in magnitude.



ASTRONOMY: ROEN KELLY

The "primary" is the pair's brighter star while the fainter sun is the "secondary." "Separation" measures the distance between the stars in arcseconds. Astronomers measure "position angle" in degrees from north (0°) through east (90°) and continuing back to north (360°).

The position angle (abbreviated P.A.) is the angle — measured from north (0°) eastward — between two imaginary lines; one is drawn from the brighter star toward celestial north and another is traced from that star through the companion. If the companion is due east of the primary, the P.A. is 90°, south 180°, and so on. The P.A. is useful to those who wish to confirm the sighting of a secondary that's faint, extremely close, or both.

But enough *talk* about double stars. Let's go outside and *experience* them. Try these early summer double stars, all of which are plotted on *Astronomy*'s monthly StarDome map (p. 38–39).

Alpha (α) Librae (magnitudes 2.7 and 5.2, 231" separation, P.A. 314°): Our warm-up double is composed of stars so bright and widely separated that you can catch them with binoculars. If you use a telescope, work with the lowest magnification. Can you detect their yellow and bluish colors?

Beta (β) Scorpii (magnitudes 2.6 and 4.5, 13.5" separation, P.A. 20°): Beta Scorpii is a must-see double star — one of the night sky's premier pairs. It's easy to resolve, even through a 2.4-inch refractor and magnifying power of just 50x. Study the companion closely. Many observers, yours truly included, note a blue-green color that contrasts nicely with the pure-white primary.

Delta (δ) Herculis (magnitudes 3.1 and 8.3, 12.8" separation, P.A. 285°): This system is a textbook example of an optical double star whose components appear side by side only by chance alignment. Like the proverbial "ships passing in the night," the fainter and more distant star is moving steadily westward at nearly a right angle to the southbound primary. One hundred twenty times fainter than the main star, the companion may be hard to discern through small scopes unless you crank up the magnification. I've seen it through a 3-inch reflector at 60x, but I recommend twice that power. If you're not positive you've captured this elusive pair, let Delta Herculis drift across the eyepiece field. Its P.A. (285°) places the secondary approximately west of the primary, and it should precede the primary as the two exit the field of view. If your suspect doesn't, you've been tricked! Increase the magnification and try again.

Alpha Herculis (magnitudes 3.5 and 5.4, 4.7" separation, P.A. 103°): This showpiece ranked sixth on a "Top Ten Doubles" survey I conducted for *Deep Sky Monthly* in the late 1970s. The colors, generally described as yellow or orange and pale blue, are exquisite! A modest-sized telescope can comfortably split Alpha Herculis, as long as you work with a magnification of 100x or greater. The companion lies roughly east of the main star.

Sigma (σ) Scorpii (magnitudes 2.9 and 8.4, 19.8" separation, P.A. 271°): With similar magnitudes but twice the separation of Delta Herculis, Sigma Scorpii is a relatively easy small-scope target. As is the case with Delta Her, the secondary drifts ahead of the primary. But unlike Delta Her, Sigma Sco is the real deal — a gravitationally bound pair separated by 420 billion miles (675 billion kilometers).

Antares (Alpha Scorpii) (magnitudes 1.0 and 5.4, 2.5" separation, P.A. 274°): We finish with a worst-case double star — a close *and* unequal duo. You'll need medium to large aperture (6 inches and up), high magnification, and steady skies to notch Antares, especially from northerly latitudes where it stands low in the southern sky. Its faint partner, which some see as a greenish speck awash in the glare of the ruddy main star, has a westerly P.A. and leads the way as the two stars traverse the field of view.

Long before skies darken enough for faint fuzzies to become visible this season, these intriguing pairs will be waiting to greet your eye. And once you've been exposed to their contagious beauty, you may find yourself stricken with double star fever!

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: Celebrate Moon Day. Clear skies!

FROM OUR INBOX

An aside, and corrections

After looking at Michael Caligiuri's picture of the Cat's Paw Nebula on p. 73 in January 2013's "Reader Gallery," I noticed the upper right "pad" of the cat's paw looks to me like a profile of a Neanderthal, or even the evolutionary "missing link." (He's facing left.) A bit below his profile, it appears he's wearing the *Star Trek* emblem on his chest. — **Jerry D. Chab,** Falls City, Nebraska

In the March 2013 Astro News story "Determining the total amount of starlight" (p. 17), the comparison of the average distance between stars in the universe is incorrect. It should say, "about 1,000 times the distance between the Sun and its nearest stellar neighbor."

The scaling in "The Sun-Earth stable points" graphic on p. 12 of the same issue is correct for Earth's L1 and L2 points, but not for the Sun-Earth distance (which is roughly 93 million miles). We apologize for the confusion. — ***Astronomy* Editors**

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

FAST FACT The winds from massive stars are at least a hundred million times stronger than the solar wind emitted by our Sun and can significantly shape their surrounding environments.

HARRY FAYT (PORTRAIT); ESA–C. CARREAU/Y. NAZÉ, ET AL. (BACKGROUND ILLUSTRATION)

Yaël Nazé Research associate at the Institute of Astrophysics and Geophysics, University of Liège, Belgium

WHAT'S NEW WITH MASSIVE STARS?

Massive stars are fascinating objects, and I like to call them the "queens" of the stars because they truly rule all aspects of life in every galaxy. They eject huge quantities of material throughout their lives in flows called stellar winds. The exact properties of such winds still remain uncertain, with values for the rates of mass-loss differing by up to two orders of magnitude. Securing an accurate knowledge of wind characteristics is important, as stellar winds inject large amounts of mass and energy into their environments, thereby affecting the whole evolution of their home galaxies. For example, winds can start or halt star formation in their neighborhoods, they change the fates of massive stars, and they are sources of chemical and mechanical feedback into the interstellar and intergalactic medium.

Winds are intrinsically unstable, and the generated shocks heat a fraction of the winds to millions of degrees, leading to X-ray emission. X-rays thus provide an important tool to uncovering the structure of stellar winds. In the past decade, Europe's X-ray observatory, XMM-Newton, has monitored one of the closest and brightest massive stars, Zeta Puppis. These unprecedented sensitive observations reveal surprising results. First, although strong X-ray variability on the timescale of hours was expected, XMM-Newton did not witness it, which implies that the wind must then be highly fragmented (more than 100,000 hot or cool pieces, a number that far exceeds theoretical predictions). The X-ray flux changes on timescales of days, however, which is linked to the presence of large-scale structures in the wind, possibly spiral-like features co-rotating with the star. Furthermore, we could pinpoint the emission zones: the X-ray emission arises from a superposition of several components, with the cooler plasma generated in large zones extending up to 100 stellar radii and the hotter plasma located in smaller zones at a few stellar radii from the star. This is the first time constraints have been placed on the location of the X-ray emission and the number of fragments in a stellar wind of an adult massive star.

ASTRONEWS

AAS LEADERS. Members of the American Astronomical Society (AAS) elected C. Megan Urry of Yale University and Chryssa Kouveliotou of NASA the AAS president and vice president, respectively, on February 13.

RUNT OF THE LITTER. This illustration of Kepler-37b shows its rocky nature. Barely larger than the Moon, it orbits its star every 13 days in a system with two other known planets. NASA/AMES/JPL-CALTECH

The universe's smallest exoplanet (yet)

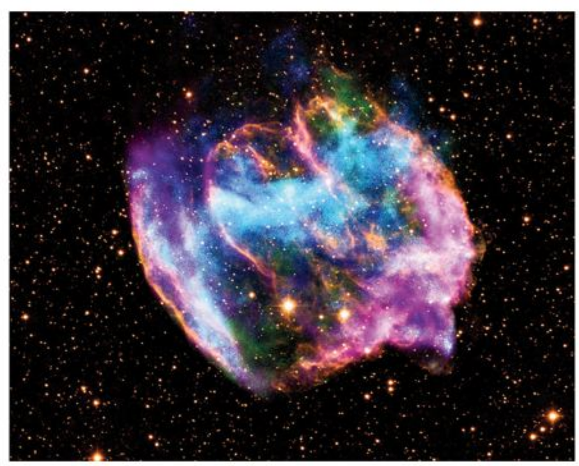
With almost 900 confirmed exoplanets and thousands more candidates, scientists are finding the universe to be a pretty planetary place. NASA's Kepler researchers now have hit another milestone in the hunt for more and different solar systems: They have found Kepler-37b, a planet that is smaller than Mercury — the most diminutive yet discovered around a normal star.

Kepler-37b, whose discovery was announced February 28 in *Nature*, is not much larger than the Moon — about one-third the size of Earth. But it is not a habitable world: In its 13-day orbit around its host star, its 800° Fahrenheit (427° Celsius) surface temperature could melt metal. It is the third confirmed planet in this system. **— S. S.**

Astronomers discover rare supernova

When most massive stars run out of fuel, their central regions collapse and trigger a chain of events that ends in a supernova explosion. The expelled stellar material blasts away from the core in a symmetrical fashion, leaving behind a uniform supernova remnant. But observations of W49B, a thousand-year-old supernova remnant, using NASA's Chandra X-ray Observatory have revealed that this object is not like many others, and the compact remnant the explosion left behind could be even more special.

According to results published in the February 10 issue of *The Astrophysical Journal*, detailed analysis of W49B indicates that this supernova remnant formed when material near the poles of a 25-solar-mass star shot out at a much higher speed than that coming from the progenitor's equator. Such an asymmetric explosion is the first of its kind that scientists have identified in the Milky Way.



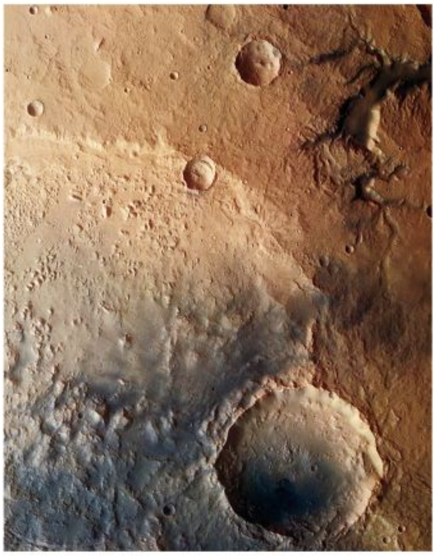
X-RAY: NASA/CXC/MIT/L. LOPEZ, ET AL.; INFRARED: PALOMAR; RADIO: NSF/NRAO/VLA

EXCEPTIONAL EXPLOSION. Supernova remnant W49B is the first of its kind to be discovered in the Milky Way, and data suggest it could harbor the most recently formed black hole in our galaxy.

And if that weren't enough, the astronomers studying W49B could not find the typical compact remnant of a supernova — a dense, spinning core called a neutron star. Lack of one leaves an interesting possibility. "It's a bit circumstantial, but we have intriguing evidence the W49B supernova also created a black hole," says co-author Daniel Castro of the Massachusetts Institute of Technology. "If that is the case, we have a rare opportunity to study a supernova responsible for creating a young black hole." **— K. F.**

ASTRO**NEWS**

DINO KILLER. A study published in the February 8 *Science* describes new high-precision radiometric dating techniques that suggest the Chicxulub asteroid impact and the dinosaur extinction occurred within just 33,000 years of each other.



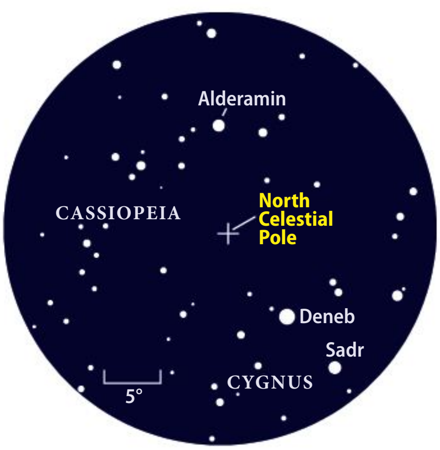
Evidence of martian water

VACANT VALLEY. Some 3.7 billion years ago, liquid water likely flowed into the 118-mile-long (190 kilometers) martian valley called Tinto Vallis, a section of which is seen in this image from the European Space Agency's Mars Express, released February 14. A number of tributaries fed into a smaller valley (top right), and both valleys fed into Palos Crater (not pictured). Scientists believe the shorter valley formed after volcanic activity turned ice under the planet's surface into water, which seeped and bubbled up to the surface. — **S. S.** ESA/DLR/G. NEUKUM (FU BERLIN)

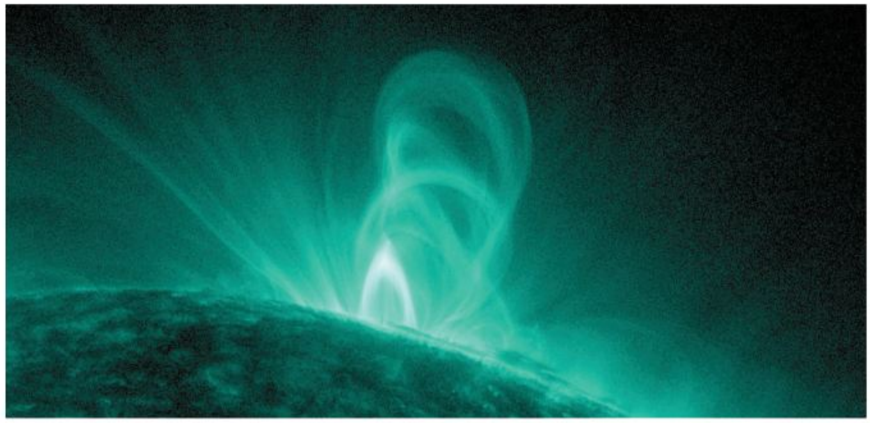
FAST FACT

The direction of Mars' axis sweeps out a 50°-wide circle on the sky that repeats every 171,000 Earth years. Earth's similar precession cycle lasts only 26,000 years.

THE SKY ABOVE MARS



MARTIAN POLE. If you stood on the north pole of Mars at night and looked straight overhead, you would see these stars. The Red Planet's axis points toward a nondescript part of the sky roughly midway between Deneb (Alpha [α] Cygni) and Alderamin (Alpha Cephei). Unlike Earth's North Celestial Pole, which currently points toward 2nd-magnitude Polaris, the martian pole aims near no naked-eye star. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY



SOLAR FORECAST. This protrusion from the surface of the Sun is known as a "flux rope" and is a knotted set of magnetic loops along which hot plasma flows. Scientists discovered that solar eruptions known as coronal mass ejections occur after such ropes separate from the Sun. NASA/SDO/GSFC

Magnetic loops foretell solar ejections

After the Sun released a coronal mass ejection (CME) July 19, 2012, scientists decided to look backward in time to see how our star behaved just before the eruption. The results of that rewind appeared in the February 20 issue of *The Astrophysical Journal*.

The Atmospheric Imaging Assembly aboard NASA's Solar Dynamics Observatory (SDO) observes the Sun all the time, recording its extreme ultraviolet activity and illuminating how our star works in real time. Because of the instrument's 24-hour watch, scientists can view data from any time since early 2010, when NASA launched the SDO.

But astronomers have never observed the details of a CME's formation. Often, the structure and activity that precede these eruptions are small and close to the surface of the star. But scientists are persistent, and when they saw the July 2012 outburst, they tried again.

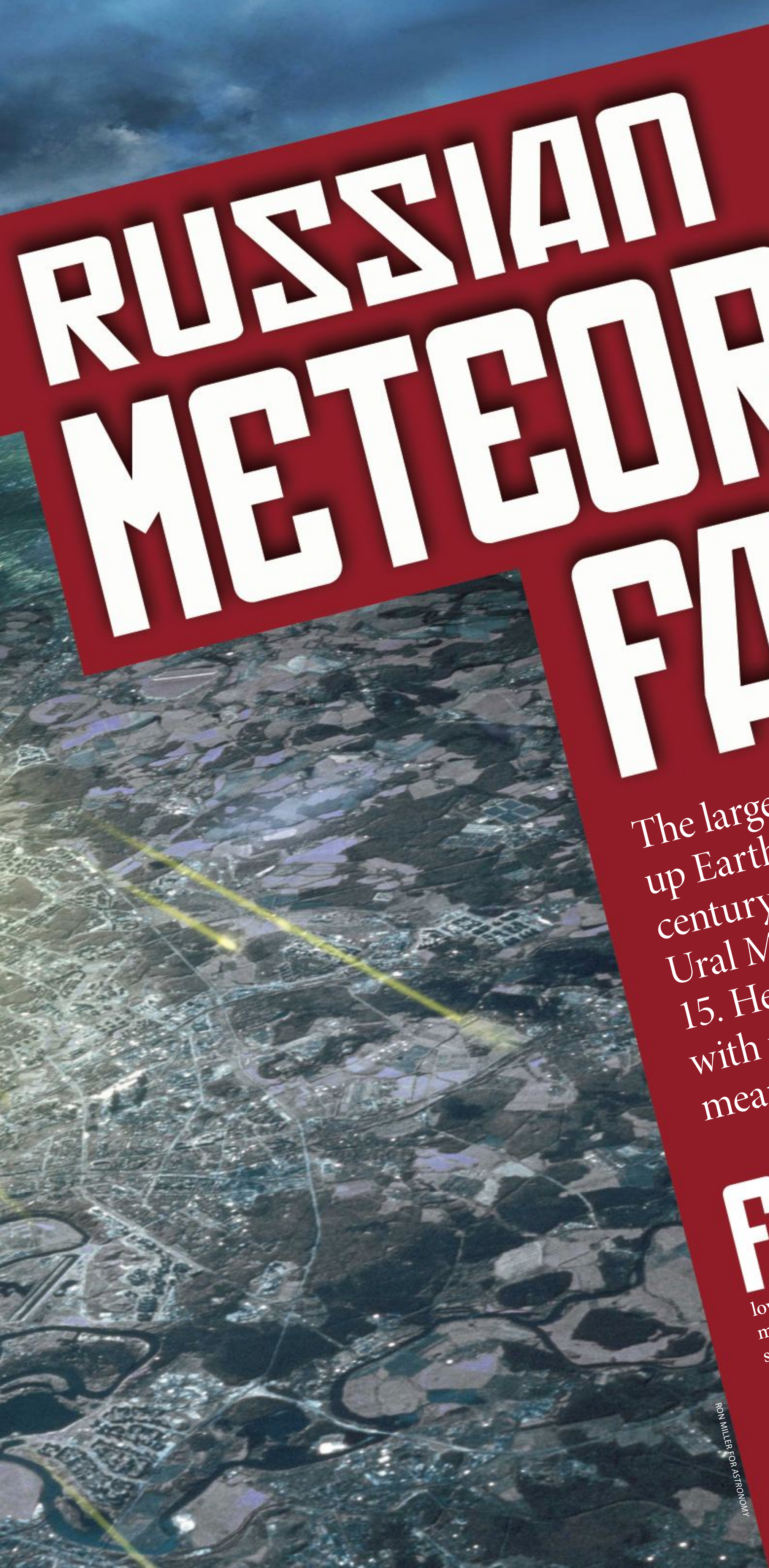
"We started going back in time," says Angelos Vourlidas, a solar scientist at the Naval Research Laboratory in Washington, D.C. "A few minutes, then an hour, then eight hours. And then we saw it."

They saw a "flux rope," a series of interacting magnetic loops along which solar plasma flows. When a flux rope breaks, billions of tons of plasma go flying into space, sometimes in Earth's direction.

Until this observation, scientists were unsure whether flux ropes formed before or coincident with CMEs. Since the structures precede the actual release of solar material into space, they can help scientists predict when these disruptive eruptions may occur. — **S. S.**

SPECIAL REPORT

2013's HISTORIC



RON MILLER FOR ASTRONOMY

RUSSIAN METEORITE FALL

The largest meteor to light up Earth's sky in more than a century exploded above Russia's Ural Mountains on February 15. Here's the inside story with pictures, analysis, and meaning. by James Oberg

For people in the Russian industrial city of Chelyabinsk just east of the Ural Mountains, Friday morning, February 15, started out as a typical late-winter day. Shortly after 9 A.M. local time, the Sun was hanging low above the southeastern horizon. The sky was mostly clear, streaked with high clouds and occasional airliner contrails. It was cold — around 16° Fahrenheit (–9° Celsius) — but not windy.

The tranquil dawn didn't last long. The first sign something unusual was happening came when the sky started to brighten dramatically in the direction of the rising Sun. Within seconds, that glare became blinding, and

TERMS TO PONDER

Was the sky show seen above Russia a meteor, fireball, or bolide? It was all three — and then some. Here's a guide to some of the terms used to describe such incidents.

ASTEROID — A rocky object, smaller than a planet, orbiting the Sun.

BOLIDE — An especially bright fireball that explodes in the atmosphere.

FIREBALL — A particularly bright meteor; scientists usually define it as being brighter than Venus (around magnitude –4).

METEOR — A streak of light in the sky that occurs when a solid particle (typically a meteoroid) enters Earth's atmosphere and air friction incinerates it.

METEORITE — A fragment of an asteroid or a meteoroid that survives its trip through the atmosphere and lands on Earth's surface.

METEOROID — A small rocky object, typically a fragment of an asteroid or comet less than a few feet (1 meter) across, that orbits the Sun. Meteoroids are invisible unless they encounter Earth.

Russian photographer Marat Akhmetaleyev was shooting landscape photos near his home when the fireball exploded. Although he thought at first it was a nuclear bomb, he still captured a series of dramatic images. This one shows the object's trail across the sky. MARAT AKHMETALEYEV

ASTRONOMY: ROEN KELLY

In its final minute, the impactor passed over northern China and Kazakhstan before exploding just south of Chelyabinsk, Russia. The mileage markers along the ground track indicate the object's altitude.

eyewitnesses saw it moving from left to right. In front of thousands of pairs of eyes and more cameras than you could count, stark shadows of lampposts, cars, and buildings swiveled across the pavement. A few viewers believed the ground was rotating.

As the brilliant first flare faded, the object's smoke trail across the southern sky forked into two parallel tracks. After two smaller flares, the paths then continued over the horizon to the southwest. Videos of the event lit up the Internet as surely as the blazing meteor lit up the sky.

A former NASA "rocket scientist," **James Oberg** *now works as a space consultant for NBC News.*

Impact on the ground

The excitement was only beginning. Nearly three minutes after the initial fireball appeared in the sky, a massive shock wave hit Chelyabinsk. Windows shattered, car alarms howled, and people screamed and cursed. A roof and wall at a zinc factory partially collapsed, and officials estimated that upward of 100,000 windows were destroyed. Remarkably, no one died, although approximately 1,500 people sought medical attention — most of them injured by flying glass.

The numbers associated with the spectacular fireball — or "superbolide," NASA's newly coined term — were as breathtaking as the event itself. The fireball traversed Earth's atmosphere at a shallow angle (about 7°) on a descending path traveling from east to west that passed about 12 miles (20 kilometers) south of Chelyabinsk. It exploded at an altitude of approximately 76,400 feet (23,300 meters) when it was moving at a velocity of 11.6 miles per second (18.6 km/s).

Friction with the atmosphere slowed and heated the incoming object. The body's rapid motion compressed the air in front of it, creating the shock wave that pulverized windows on the ground. The compression also heated atmospheric gases and stripped electrons from the atoms and molecules in a process called ionization. When the electrons recombined with the ionized gases, they emitted the light seen in the Russian sky. The energy caused the space rock to break up and ultimately explode when the growing pressure exceeded the object's internal strength.

The force radiated by the main fireball reached about 90 kilotons. In comparison, the atomic bomb detonated above Hiroshima in 1945 topped out at roughly 15 kilotons. The impact dumped even more energy into the upper atmosphere along the descent

RIA NOVOSTI/CAMERA PRESS/REDUX

Automobile dashcams delivered the first images of the meteor's appearance and were a godsend for scientists trying to reconstruct the object's path.

XINHUA/RIA/CORBIS

The meteor's fading smoke trail hangs in the air above Chelyabinsk, a Russian city with roughly a million residents that lies just east of the Ural Mountains.

path, although less explosively. NASA scientists estimate the total energy delivered during the entire entry at 440 kilotons.

The Chelyabinsk blast is easily the most energetic impact event witnessed since 1908, when an even larger object exploded above the Tunguska region in south-central Siberia. Researchers think the Tunguska explosion, which flattened some 770 square miles (2,000 square km) of forest, released between 3 and 5 megatons of energy.

Fragments of the Chelyabinsk impactor that reached the ground appear to be ordinary chondrite meteorites. These have typical densities of about 3.6 grams per cubic centimeter. To deliver 440 kilotons of energy, the incoming object would have needed to be 60 feet (18m) in diameter and have a mass of roughly 11,000 tons. The object unquestionably was an asteroid, albeit a small one.

A Cold War flashback

It seems almost remarkable that scientists could learn so much about the superbolide and the object that created it within just a couple of weeks. But at the moment when the fireball burst on the scene, at 9:21 A.M. local time (10:21 P.M. EST on February 14), "confusion" was the operative word. Both in the city and around the globe, the first and most important question — then, and even now in hindsight — was: Where did this object come from? The quest for information wasn't mere idle curiosity.

For the Russians in Chelyabinsk that day, the object obviously approached from the east, out of the rising Sun and from the direction of China. Some people initially panicked and thought that it might be a

A zinc factory in Chelyabinsk lost part of its roof and wall (above) when the fireball's shock wave hit, although production continued normally. Officials estimate that the blast destroyed more than 100,000 windows (upper right); damage cleanup started right away (lower right). XINHUA/RIA/CORBIS (ABOVE); RIA NOVOSTI/CAMERA PRESS/REDUX (UPPER RIGHT); ANDREI LADYGIN/ZUMA PRESS/CORBIS (LOWER RIGHT)

nuclear attack from that country. Fortunately, those fears were short-lived.

Only one of the million humans in the target zone was prepared for the worst. Teacher Yuliya Karbysheva was with her elementary school class — 44 children in all — at School #37 in Chelyabinsk. When a flare like a second Sun bathed her east-facing classroom in blinding light, the children ran to the window. But she remembered the air-raid drills of her own childhood during the Cold War and ordered the children under their desks.

As they ducked and covered, she quickly opened the glass doors between the classrooms, another half-remembered emergency measure preached during the old drills. But as one minute passed, then another, the children's curiosity grew. She moved toward the windows to wave her antsy charges back under their desks.

It was there that the blast wave caught her, showering her with glass that inflicted severe arm cuts but nothing life-threatening. Covered with her own blood, she calmly ordered the children to get their coats and evacuate the building.

Amid all the confusion and rumors and fear of that day, Karbysheva quickly became the city's hero. Not a single child had even been scratched. One person, at least, had recognized the warning signs and taken measures to mitigate the effects.

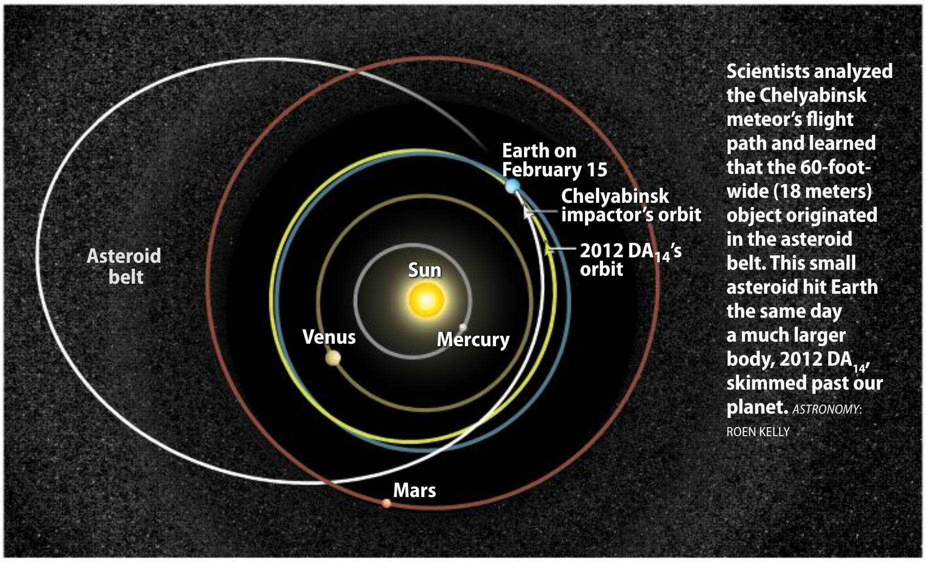
Visit from the asteroid belt

Once the initial pandemonium subsided, scientists got to work figuring out where the diminutive asteroid had originated. An underappreciated feature of Russian life facilitated the process. Many cars carry dashboard-mounted webcams — dashcams — that record a continuous loop of images. They have nothing to do with scientific studies of fireball tracking. Instead, recent years have seen increasingly corrupt traffic police as well as automobile accidents staged for insurance fraud. The dashcams provide visual records of the accidents.

Within hours of the incident, dozens of these videos appeared on the Internet. In some, the fireball flared into visibility right in the field of view. In others, the passing fireball's glare cast shadows of telephone poles onto streets. Once researchers determined a street's orientation, they could reconstruct the precise elevations and azimuths with respect to time.

Determining the object's original path through space had an urgency unusual for computational astronomy. Only 16 hours after the Chelyabinsk impact, an even bigger object would make a remarkably close flyby of Earth. Asteroid 2012 DA_{14} measures about 100 feet (30m) across and has a mass estimated at 40,000 tons.

Spanish astronomers discovered this object in February 2012 during a previous close encounter with Earth. Scientists calculated that it would pass 17,200 miles (27,700km) above Earth's surface — closer than many communications satellites orbit. But it was also so close that Earth's gravity flung it onto a new path that lies almost



Scientists analyzed the Chelyabinsk meteor's flight path and learned that the 60-foot-wide (18 meters) object originated in the asteroid belt. This small asteroid hit Earth the same day a much larger body, 2012 DA_{14}, skimmed past our planet. *ASTRONOMY*: ROEN KELLY

entirely inside our planet's orbit. Its greatest distance from the Sun dropped by 11 million miles (18 million km), and its period shortened from 368 days to 317 days.

Of immediate concern to astronomers, the general public, and emergency preparedness teams around the world was whether the Chelyabinsk fireball was associated in any way with 2012 DA_{14}. Astronomers were not aware that any debris accompanied the larger asteroid, but a relatively recent impact or fragmentation could have littered its orbit with some sizable rubble.

It seemed to defy probability that two such extremely rare events occurred so close together and were not related. Yet that's exactly what the earliest estimates of the Chelyabinsk object's orbit suggested.

Some scientists based their first guesses on a quick analysis of the dashcam videos. Others relied on the impact's happening in the Northern Hemisphere, which was out of the line of sight of DA_{14}'s approach.

More precise measurements over the next day or two confirmed these reassuring guesses. This result enormously lowered the likelihood that any other object from the same potential swarm would hit Earth during the coming days. And none ever did.

When astronomers ultimately pinpointed the Chelyabinsk fireball's pre-impact path, they found it had been a fairly typical Apollo asteroid — the largest class of asteroids whose orbits cross Earth's. The Russian object's orbit ranged from the asteroid belt inward as far as the orbit of Venus and lay close to the orbital planes of the major planets. Statistically, thousands of objects of similar size must exist.

NASA's final report, authored by Don Yeomans and Paul Chodas, two experts on near-Earth asteroids at the Jet Propulsion Laboratory, also computed the object's trajectory as it approached Earth. The impactor bore down on our planet along a path that remained within 15° of the Sun's direction. As NASA noted, Earth-based telescopes seeking to detect asteroids cannot scan regions of the sky this close to the Sun.

The hunt for fragments

People in the Chelyabinsk area certainly had to deal with the bad fortune of being hit by the biggest space impactor in a century. Yet they were lucky when it came time to search for meteorite fragments — the wintry climate provided a perfect setting.

First, a blanket of snow across the region offered an ideal backdrop on which to seek dark crumbly meteorites. Second, the weather after the event was crisp and clear, yielding perfect lighting for the search.

SERGEI ILNITSKY/CORBIS

Scientists suspect that a fragment of the incoming asteroid blasted this 26-foot-wide (8 meters) hole in frozen Chebarkul Lake, which is located about 5 miles (8 kilometers) from Chelyabinsk.

RIA NOVOSTI/CAMERA PRESS/REDUX

A researcher holds a meteorite found on the ice surrounding the gaping hole at Chebarkul Lake.

And there were plenty of searchers, few of whom were motivated by science. Within hours of the fall, "recovered meteorites" for sale flooded the Internet, and some even looked genuine. Along with the meteorites, there were the usual "meteor-wrongs" — honest misidentifications in many cases — and a collection of obvious hoaxes.

A hole in the ice at nearby Chebarkul Lake created a brief flap. Such holes can appear naturally, but researchers suspected a meteor fragment blew the hole. Officials found what were later confirmed as meteorites on the ice surrounding the hole.

Yeomans and Chodas reported that authentic fragments were silicate-rich ordinary chondrites, the type that constitutes about 80 percent of all meteorite falls. This was the last nail in the coffin to prove Chelyabinsk was unrelated to the 2012 DA_{14} flyby. Spectral observations of the larger asteroid show it has a composition similar to certain types of carbonaceous chondrite meteorites with abundant inclusions of calcium and aluminum. This is quite different from the silicate-rich ordinary chondrite meteorites from Chelyabinsk.

Now that scientists have settled what the Chelyabinsk object was not, and that its orbit placed it squarely in the group of Apollo asteroids known for more than a century, speculation has turned to what the object was in a larger sense.

It was a reminder that statistics don't lie and that Earth is not immune from impacts that can cause significant damage. It also showed that Earth-based programs seeking such objects have a long way to go. Although NASA estimates that scientists have found at least 90 percent of the potentially hazardous objects 0.6 mile (1km) in diameter or larger, they fall well short of that percentage when it comes to bodies the size of 2012 DA_{14}. And no one knows how many Chelyabinsk-sized objects lurk in our planet's vicinity.

The technology for monitoring space for potentially hazardous objects continues to improve. Still, detecting bodies approaching from the Sun's direction, like the Chelyabinsk impactor, requires telescopes far out in space. By the end of this decade, scientists expect that they will have found 90 percent of the most dangerous objects, those with diameters larger than 500 feet (150m). The Chelyabinsk fireball and the near-miss of 2012 DA_{14} seem to have strengthened the push for better warning systems. And they certainly focused public and political attention on the need to develop active countermeasures to defend our planet.

LEARN ABOUT THE SOUNDS CREATED BY THE RUSSIAN METEOR AND WHAT THE MEDIA GOT WRONG AT **www.Astronomy.com/toc.**

BUZZ ALDRIN on our future in space

From Moon rovers practicing in Hawaii to astronauts controlling lunar robots from space, **Buzz Aldrin** depicts the legacy and the future of space exploration.

President Kennedy said send a man to the Moon and bring him back safely — a man. We could have satisfied that goal by having a person land on the lunar surface, look out the window, maybe deploy a robot, but not open the hatch to the environment. Instead, we chose to have two astronauts moonwalk.

Thanks to that decision, Neil Armstrong and I stood on the shores of an inhospitable, desolate, yet magnificent landscape. Looking at Earth from that perspective, everything I knew and loved lay suspended overhead, residing on a small, fragile, bright blue sphere engulfed by the blackness of space.

America's success in first landing humans on the Moon was viewed as a success for all humankind. People took pride in collectively declaring, "We did it." In undertaking the Apollo 11 mission, there was a rediscovery of our own precious planet Earth.

Buzz Aldrin *is a former Gemini and Apollo astronaut. Reprinted by arrangement with the National Geographic Society from the book* Mission to Mars: My Vision for Space Exploration, *by Buzz Aldrin with Leonard David.*

Buzz Aldrin was the second person to walk on the Moon and has continued to advocate space exploration — both public and private — even as humans' presence on other worlds has declined. NATIONAL GEOGRAPHIC SOCIETY

▲ **From orbit, Buzz Aldrin saw Earth contrasting with the Moon's "magnificent desolation," and snapped this picture.** BUZZ ALDRIN/NASA

◄ **Buzz Aldrin and Neil Armstrong trained on Earth for the procedures they would have to complete in space, much as modern lunar exploration companies test their vehicles at Earth-analog locations. Here, they rehearsed sampling "lunar soil."** NASA

In looking back at that moment in time, putting aside all the pre-mission training, there wasn't a big picture in my mind of the sequence of what we were doing. We were never briefed on how important the public-relations pictures would be.

Our stay-time on the Moon was brief. But the emotion of being first has been long-lasting. Still, as we both walked on the Moon, I did have the sense of not being as much a member of a team as a follower. If Neil started to do the wrong thing, I wouldn't have known, because I wasn't following a particular order of what we were doing. In some ways, we were thrown out onto the surface and expected to perform a checklist by memory. Set up the flag. Open rock boxes. Put an experiment in place.

It was very extemporaneous. There was a sense of, "Well, we're here. Let's go do what we're supposed to do. But what is next?" The later Apollo moonwalkers had a little more time to get used to the lunar environment.

Before we left Earth, some alarmists considered the lunar dust very dangerous, in fact pyrophoric — capable of igniting spontaneously in air. The theory was that the lunar dust had been so void of contact with oxygen that as soon as we repressurized our lunar module cabin, it might heat up, smolder, and perhaps burst into flames. At least that was the worry of a few. A late July fireworks display on the Moon was not something anyone wanted!

The official samples collected from the Moon's surface were placed in vacuum-packed containers. Neil did grab a contingency specimen. He stuffed it into his thigh space suit pocket, just in case there was a problem that forced us to scurry off the Moon in a hurry.

"Earth's **Moon** is a celestial body with a story to tell."

So, following our moonwalks, first I then Neil climbed back on board the lander. That grab specimen was placed on the cylindrical flat top of the ascent engine cover. As the cabin began to fill with air, we both anxiously waited to see if the lunar sample would begin to smoke and smolder. If it did, we'd stop pressurization, open the hatch, and toss it out. But nothing happened. We got back to the business of readying for departure from the Moon.

Yes, Apollo 11 was historic, but it was fraught with risks. When we finally set the *Eagle* lander down, we had only an estimated 16 seconds of fuel left. On the surface, *if* we had fallen and torn a suit, there wasn't much chance of survival. *If* the one ascent engine didn't ignite or *if* the onboard computer had a glitch, we would never have left the Moon. *If* the rendezvous with Mike Collins, circling the Moon in the command module, hadn't gone flawlessly, we then would have faced rather nasty consequences. That's just a few of a string of "*ifs*."

In recent years, a document has surfaced that was authored by William Safire, then President Nixon's speechwriter, about our Apollo Moon mission.

In a July 18, 1969, statement to White House official H. R. Haldeman, Safire titled his internal White House essay "In Event of Moon Disaster" and included this ominous phrasing: "Fate has ordained that the men who went to the Moon to explore in peace will stay on the Moon to rest in peace."

Calling us brave men, the speech went on to acknowledge that Armstrong and Aldrin know "there is no hope for their recovery."

"In ancient days, men looked at stars and saw their heroes in the constellations," the statement continued. "In modern times, we do much the same, but our heroes are epic men of flesh and blood.

"In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man."

As odd a statement as that sounds today, it didn't surprise me. Senior officials must always be prepared with remarks for breakthroughs as well as tragedies. Apollo 11 had the potential to fit into either one of those categories. Reading the prepared eulogy, I am proud that our mission accomplished the same goals — and brought us back home safely.

A different place

The Moon is a different place since I traveled there in 1969.

It is obvious that Earth's Moon is a celestial body with a story to tell. It has the scars to prove it — a cratered, battered, and beat-up world that is a witness plate to 4.5 billion years of violent processes that showcase the evolution of our solar system.

Thanks to a fleet of robotic probes recently sent to the Moon by several

The Saturn V rocket that launched Apollo astronauts toward the Moon functions much the same way and is structured similarly to rockets today, even though the cargo they carry is technologically different. NASA

countries, there's verification that the Moon is a mother lode of useful materials. Furthermore, the Moon appears to be chemically active and has a full-fledged water cycle.

New data on our old, time-weathered Moon point to water there in the form of mostly pure ice crystals in some places. For example, sunlight-starved craters at the poles of the Moon — called "cold traps" — can harbor water-ice deposits. Gaining access to this resource is a step toward using it for life support to sustain human explorers. Similarly, the Moon is rife with hydrogen gas, ammonia, and methane, all of which can be converted to rocket propellant.

Fresh findings about the Moon have revealed the lunar poles to be lively places filled with complex volatiles, unique physics, and odd chemistry, all available at super-cold temperatures. Recently, the first Lunar Superconductor Applications Workshop brought together expert groups in high-temperature superconductors, low-temperature electronics, cryogenic engineering, and lunar science. Even dealing with below-100 kelvin (–279° Fahrenheit) temperatures on the Moon, there are several high-temperature superconductors to select from; substances like sapphire and beryllium become thermal superconductors. Digital and analog circuits can operate at very low power and very high speeds, with low noise and high fidelity.

Harnessing the exotic sparks innovation and creativity. What kind of power generation and storage systems can operate for long periods of time that take advantage of the wild swing of lunar temperatures? There's already discussion of lightweight, modular, and expandable superconducting magnets that could provide radiation shielding on the Moon. Those permanently shadowed, incredibly frigid areas at the Moon's poles might also be ideally suited for infrared telescope observations.

In short, our celestial neighbor in gravitational lock, the Moon, can be tapped to help create a sustainable, economic, industrial, and science-generating expansion into space.

The question is, "What should America's role be in replanting footprints on the Moon?"

Preservation

Standing on the talcum-like lunar dust a few feet from the *Eagle*, I labeled the landscape we stood upon "magnificent desolation."

NEIL ARMSTRONG/NASA

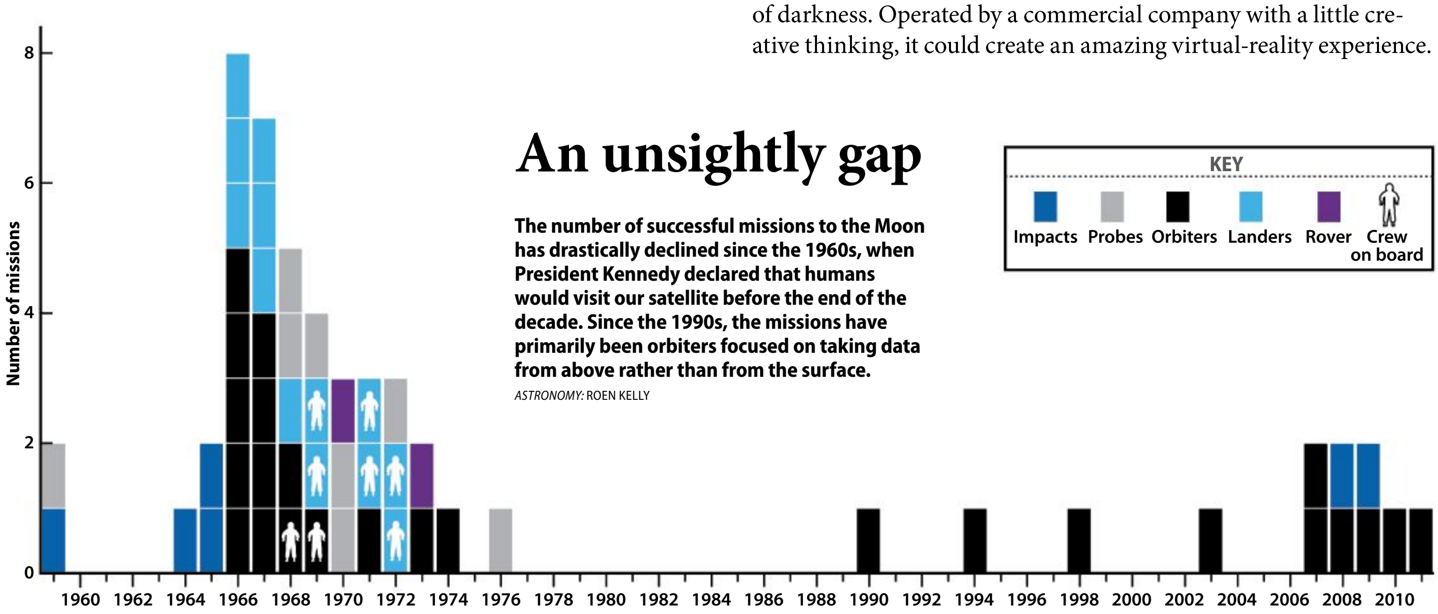
Buzz Aldrin, taking his first steps toward the Moon, did not know at first what to expect of Earth's satellite or of his role in history. Since his moonwalk, he has continued to emphasize the importance of humanity's role in space.

There were six Apollo lunar landing missions from 1969 to the close of 1972, and just 12 of us were fortunate to kick up dust on the Moon. Somebody tagged us the "Dusty Dozen." The accumulated moonwalking time was limited: From Apollo 11's modest two and a half hours to Apollo 17's campaign of forays, it added up to a little over 22 hours. Quite literally, exploration of the Moon — both robotic and human — has barely scratched the surface.

There's a campaign to designate the Tranquility Base site, where Neil and I landed, as a national historic landmark. NASA itself has put together guidelines on how to protect and preserve the historic and scientific value of U.S. government lunar artifacts. The field of space heritage preservation is gaining traction.

I'm an advocate for preserving all six Apollo landing sites. By expending the effort to safeguard Apollo 11's Tranquillity Base, we will learn how best to preserve the other five Apollo landing spots.

The historic landing location could be isolated, encircled by movable cameras that would be trained on the spot. The lighting conditions would change, given the 14 days of sunlight and 14 days of darkness. Operated by a commercial company with a little creative thinking, it could create an amazing virtual-reality experience.



An unsightly gap

The number of successful missions to the Moon has drastically declined since the 1960s, when President Kennedy declared that humans would visit our satellite before the end of the decade. Since the 1990s, the missions have primarily been orbiters focused on taking data from above rather than from the surface.

ASTRONOMY: ROEN KELLY

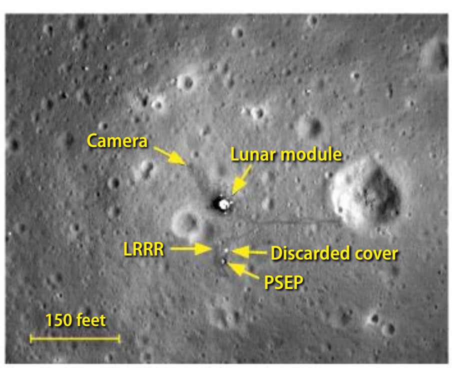
▲ **NASA and private spaceflight companies research their rovers' behavior in parts of Earth that resemble the lunar landscape. In this image, a rover that is part of the In-Situ Resource Utilization analog mission explores a site at the Pacific International Space Center for Exploration Systems (PISCES) in Hawaii.** PISCES

◄ **Buzz Aldrin, like today's rovers, practiced exploring analog environments.** NASA

I have looked over the superb forget-me-not images taken from Moon orbit by NASA's Lunar Reconnaissance Orbiter that clearly show Eagle's landing site. The sharpshooting camera specialist is Mark Robinson at Arizona State University's School of Earth and Space Exploration in Tempe. He is principal investigator for the Lunar Reconnaissance Orbiter Camera.

You can make out the remnants of our first steps as dark regions around the lunar module and in dark tracks that lead to the scientific experiments Neil and I set up. Another trail leads toward Little West Crater, to the east of our *Eagle* lander. Neil took this jaunt near the end of the two and a half hours we spent moonwalking to look inside the crater. This was the farthest either of us ventured from the landing site. Overall, our tracks in kicking up the lunar dust cover less area than a typical city block.

Robinson observes that hardware launched from Earth and sitting on the Moon has been resting there for 40 to 50 years now. Talk about a long-duration-exposure material sciences experiment, he explains, given radiation, vacuum, temperature cycling, and micrometeorite bombardment. How have electronics fared? Optics? Paint? Coatings? Metals? Synthetics? In future years, on-the-spot observations and recovery of a modest amount of these materials would be a boon to engineers building lunar hardware, Robinson says. Waste bags tossed out by Apollo crews might make for an interesting biology experiment. Are any microbes still alive among the garbage and human waste left on the Moon? If so, can we see evidence of adaptation to the harsh lunar environment?



The Lunar Reconnaissance Orbiter took images showing the locations of Apollo landings, such as this image showing the Apollo 11 lunar module (center) and the mission's experiments, such as the Lunar Laser Ranging experiment (LRRR) and the Passive Seismic Experiment Package (PSEP). NASA/GSFC/ARIZONA STATE UNIVERSITY

In May 2012, NASA and the X Prize Foundation of Playa Vista, California, announced that the Google Lunar X Prize, a $30 million competition for the first privately funded team to send a robot to the Moon, is also recognizing NASA guidelines to guard lunar historic sites and preserve ongoing and future science on the Moon.

I have been wondering if one of those teams might have its robot recover Alan Shepard's golf balls that he hit during his Apollo 14 Moon-landing mission.

Maybe with all the craters, he managed to get a hole in one?

The ultimately abandoned Constellation Program would have sent astronauts to the Moon around 2015. The Ares V, illustrated here, was to launch a lunar module and crew to explore the challenge of living and working in harsh alien environments. NASA

The Bush push

In January 2004, President George W. Bush put NASA in high gear, heading back to the Moon with a space vision that was to have set in motion future exploration of Mars and other destinations. The Bush space policy focused on U.S. astronauts first returning to the Moon as early as 2015 and no later than 2020.

Portraying the Moon as home to abundant resources, President Bush did underscore the availability of raw materials that might be harvested and processed into rocket fuel or breathable air. "We can use our time on the Moon to develop and test new approaches and technologies and systems that will allow us to function in other, more challenging environments. The Moon is a logical step toward further progress and achievement," he remarked in rolling out his space policy.

To fulfill the Bush space agenda required expensive new rockets — the Ares I launcher and the large, unfunded Ares V booster — plus a new lunar module, all elements of the Constellation Program.

The Bush plan forced retirement of the space shuttle in 2010 to pay for the return to the Moon. Putting the shuttle out to pasture created a large human spaceflight gap in reaching the International Space Station. The price tag for building the station is roughly $100 billion, and without the space shuttle, there's no way to reach it without Russian assistance.

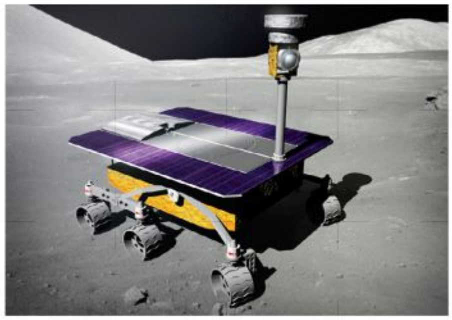
In the end, the stars of Constellation were out of financial alignment. It was an impossible policy to implement given limited NASA money.

Today, I see the Moon in a different light from that of the "space race" days of 1969. I envision a 21st-century Moon, one that can be transformed into an "International Lunar Development Authority." This entity would set the stage for establishment of infrastructure that not only taps the resource-rich Moon by commercial, private-sector groups, but also spurs international partnerships between nations.

America can lead the way in creating a lunar consortium of robotic base-building that embraces the talents of China, Europe,

Private spaceflight companies such as White Label Space, which designed the orbiter and lander illustrated above, are competing for the Google Lunar X Prize of $30 million to send a robot to the Moon. WHITE LABEL SPACE

"Today, I see the **Moon** in a different light from that of the 'space race' days of 1969."



Once on the Moon, the robot whose design wins the Google Lunar X Prize will explore the lunar surface and take scientific data and samples, much like the Curiosity rover currently does on Mars. WHITE LABEL SPACE

The Moon Express Lander Test Vehicle, a prototype lunar lander system developed in partnership with NASA, is also competing for the Google Lunar X Prize. It is reminiscent of the Apollo landers, though the technology it carries is more advanced. NASA

Russia, India, Japan, and others to establish a firm — this time permanent — foothold on the Moon. In doing so, the United States can sharpen its own technological know-how that's needed to eventually homestead the Red Planet.

For several years, I have been working shoulder to shoulder with a group of engineers and scientists engaged in a vital initiative: an International Lunar Research Park. This base will first be anchored in Hawaii and later evolve to the Moon. The project is being carried out under the wing of the Pacific International Space Center for Exploration Systems, or PISCES for short. PISCES would drive the development of surface systems and other hardware for the Moon, be it for energy production and storage, recycling, construction, or mining, and spark a host of resource-utilization technologies and techniques. Those working on this base have coined a phrase: "Dust to Thrust."

Hawaii and the Moon — the coupling brings back memories. In the 1960s, prior to my Apollo 11 flight, NASA made use of the lower slopes of Mauna Kea on the Big Island of Hawaii. It was a training ground for Apollo astronauts to help us experience what the surface of the Moon would be like and how best to work there. In fact, of all the places on Earth where we trained, the Big Island most felt like the Moon.

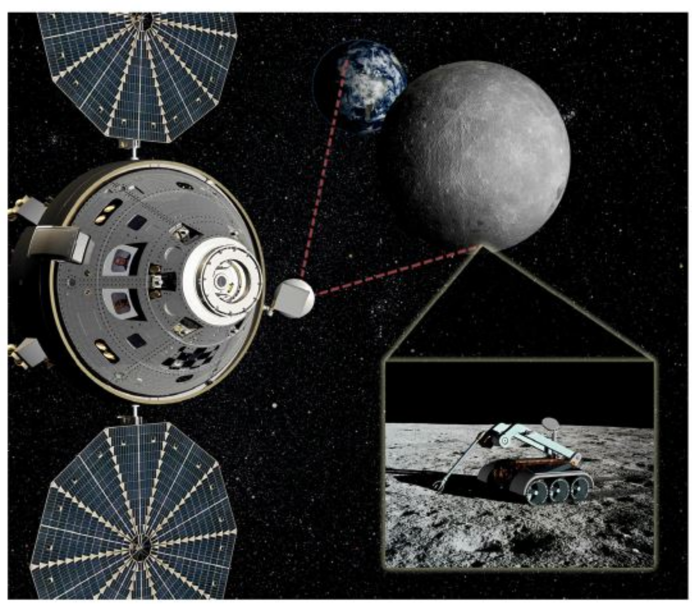
The proposed International Lunar Research Park can become a unique multinational facility, a test site to be replicated on the Moon. A goal of this venture is for the United States to acquire the skills for remotely operating robotic systems and knowledge useful to connect habitats, perform habitat-maintenance tasks, set up scientific experiments, and run mobile prospecting gear capable of mining the Moon.

Decades ago, there was only one way to put human cognition on the Moon. That was the expensive proposition of hurling people and their brainpower there. Today it's no longer the only choice.

Advances in telerobotics can plant human cognition and dexterity on the Moon. Telerobotics is an explosive-growth industry here on Earth. We plunge to great ocean depths using human-controlled automatons. Robotic equipment extracts resources from perilous mines. Our skies are increasingly dotted with craft winging their way under telecontrol. Even high-precision surgery is done via telerobotics, carried out by a doctor distant from the patient.

Safely tucked inside a high-tech habitat at an Earth-Moon Lagrangian point, space expeditionary crews can teleoperate systems that are deployed on the Moon.

By demonstrating telerobotic skills at the Hawaii-situated base, processes will be validated in preparation for renewed human activity on the Moon. This matchless center will motivate and train the much-needed next generation of engineers, scientists, and entrepreneurs primed to take on the challenges ahead in developing the space frontier. I know firsthand, challenging times often precede the most rewarding moments.



A robot on the Moon's surface could be controlled from an Earth-Moon Lagrangian point, where an object can have a constant orbit between two larger bodies. In this case, humans in a space outpost would orbit between Earth and the Moon and would control a lunar rover from there, instead of from Earth. LOCKHEED MARTIN

TO LEARN MORE ABOUT FUTURE MISSIONS TO THE MOON, VISIT **www.Astronomy.com/toc.**

How to find ET with

The search for extraterrestrial intelligence has mostly revolved around radio signal detection, but such a civilization's heat signature also could give away its location. **by Jeff R. Kuhn, Svetlana V. Berdyugina, David Halliday, and Caisey Harlingten**

More than 50 years ago, while discussing the lack of evidence of extraterrestrials during a lunchtime conversation with colleagues, physicist Enrico Fermi voiced the famous question: Why do we seem to be alone in the universe? His query is now even more perplexing given the large number of planets that NASA's Kepler mission and other projects have discovered. In fact, Kepler scientists say that more than half of stars host at least one world. Another study found that about one-third of stars similar to the Sun likely harbor at least one Earth-sized or larger planet orbiting in the star's habitable zone (HZ) — a region with the right temperature to allow liquid water on a world's surface.

Our exploding awareness of extrasolar planets in our cosmic neighborhood makes the alien silence more than a bit mysterious. Is advanced life so tenuous and short-lived that no civilization ever advances to a point where it can reach out to its cosmic neighbors? Perhaps the eerie silence reflects a well-developed survival instinct to avoid calling attention to itself for fear of, for example, being eaten?

If we, as humans, could uncover extraterrestrial civilizations (ETCs) without announcing ourselves, it seems possible that we would learn something about how to prolong our planet's occupancy. Current and emerging earthbound technology makes it possible to obtain a census of ETCs within about 60 light-years of us — just by evaluating the heat signatures of nearby stars. With this in mind, we organized a team of engineers and scientists devoted to planning and constructing a ground-based instrument that has the ability to detect nearby ETCs within five to 10 years.

Jeff R. Kuhn, *from the University of Hawaii's Institute for Astronomy, is the Colossus project leader.* **Svetlana V. Berdyugina** *of the University of Freiburg and the Kiepenheuer Institute for Solar Physics in Germany;* **David Halliday** *of Dynamic Structures, Ltd. in British Columbia, Canada; and* **Caisey Harlingten** *of the Searchlight Observatory Network in The Grange, Norwich, England, are founding members of the Colossus project.*

Thermal tracking

Hunting for ETCs on the basis of unknowable alien sociologies is like participating in a search party that isn't sure of what it's seeking. So far, most searches for extraterrestrial intelligence have sought beamed messages from presumed gregarious ETCs. But there's an alternative: looking for an unintentional or unavoidable ETC signal.

In the 1960s, physicist and mathematician Freeman Dyson first suggested that an extremely advanced civilization might satisfy its power needs by capturing the total luminosity of its host star. Perhaps the ETC would build a spherical structure surrounding the star with a radius from the planet to that sun — a "Dyson sphere." The ETC would then reradiate into space the waste energy, with an infrared radiation profile similar to the planet's natural heat. Thus, a way to find such an advanced ETC (which would be far more technologically innovative than Earth-based societies) is to look for stars that are invisible or faint at optical wavelengths but bright in infrared emission.

Unfortunately, a recent search for these Dyson spheres using data of some 250,000 sources in the all-sky Infrared Astronomical Satellite catalog came up empty.

Current technology, however, makes it possible to find even weaker heat signals from less advanced (and, therefore, Earth-like) ETCs. These signals aren't from a

infrared light

An extremely technologically advanced civilization might build a mechanism to harness all of its star's energy, instead of the small fraction that a planet typically receives. Searches for such a "Dyson sphere" have so far come up empty. LYNETTE COOK FOR *ASTRONOMY*

On Earth, civilization geographically clusters, as shown in this image of the infrared radiation from lighting at night across Europe, Africa, and the Middle East. NASA EARTH OBSERVATORY AND NOAA NATIONAL GEOPHYSICAL DATA CENTER

star-enclosing power source (like the Dyson sphere), but instead from the civilized planet directly. Any Earth-like ETC uses power, and by the laws of thermodynamics, that power eventually shows up in the planetary environment as heat. This consequence is as unavoidable as death or taxes, and it gives scientists a method for possibly finding ETCs on planets orbiting nearby stars. The consequences of a sensitive search, regardless of the outcome, might help us understand how fragile civilization on Earth really is. A tool for understanding this is similar to SETI astronomer Frank Drake's equation used to estimate the likely number of Milky Way civilizations.

We can estimate how likely it is for an Earth-like civilization to survive by examining all of the bright stars within about 60 light-years of the Sun (N_S) and postulating that civilizations that develop on planets within their stars' HZs either live on forever or become extinct within a few thousand years, and that they can be detected, even if they don't want to be spotted. In our study, N_S is 600, the fraction of stars that have planets (f_P) is about 0.5, and the number of those worlds that are in the HZ (n_{HZ}) is perhaps 0.5. If we restrain humans' bias of self-importance in the universe, then we can expect that the fraction of those planets that develop civilizations (f_C) and the fraction of those civilizations that are more advanced than Earth's (f_{BE}) are both 0.5. The above estimates yield the number of ETCs detected by such a census: $N_D = N_S f_P n_{HZ} f_C f_{BE} f_S = 38f_S$, where N_D is the number of ETCs detected and f_S is the fraction of civilizations that are "successful." f_S is what we can learn from an ETC census.

Even if only one in 20 advanced civilizations survive, we will get a detection. And if we don't find any signal, it would lead to the important conclusion that any given ETC has at most a few percent chance of surviving after it reaches a certain technological level. So, how could we carry out this census?

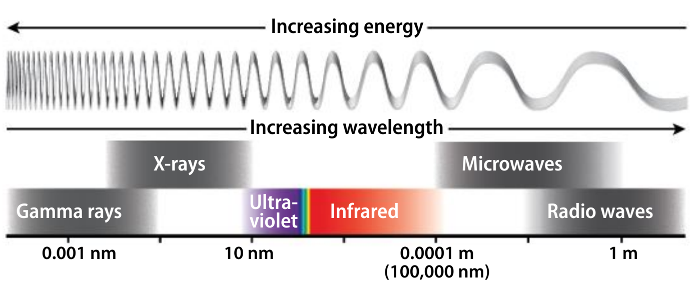
As energy usage increases

The energy footprint of life and civilization appears as infrared heat radiation, and a convenient way to describe the strength of this signal is in terms of the total stellar power that is incident on the host planet. Earth's current global terrestrial power production is 15 million million watts (terawatts) — that's 0.04 percent of the total solar power Earth intercepts. (Let's call the ratio of an ETC's power production to the amount of solar power it receives Ω.) Meanwhile, the total power used for photosynthesis on Earth is about 0.2 percent of the total light falling on the planet from the Sun; it fuels most of the terrestrial food chain and illustrates that Earth's civilizations consume only 20 percent as much power as biological processes. The power we radiate into space from our lighting is less than 10 percent of the total human power consumption.

A large infrared-sensitive telescope could observe even those civilizations that utilize 1 percent of the total solar power they intercept.

As Earth-like civilizations evolve, they use more power. For example, in Roman times, we estimate Ω was about 1/1,000 what it is today. Humans' global power consumption is growing by about 2.5 percent per year, even though the world's population is growing at less than half this rate. In contrast, our knowledge base (the combined total of all recorded information) doubles in just two years. As cultures advance, their information

Radiation differences



The electromagnetic spectrum spans a huge range of energies. While we're most familiar with visible light, astronomers have instruments that can observe radio waves, gamma rays, and everything in between. The research described in this article focuses on infrared emission. *ASTRONOMY*: ROEN KELLY

content also must grow, and the power required to manipulate this knowledge eventually dominates a civilization's total power use.

Naturally absorbed starlight heats the planet, but a civilization's power generation also contributes to the global temperature. The best energy policy for such a civilization would be to absorb and utilize the power from *all* incident starlight; this would both heat the planet and power the ETC's needs. It also would decrease the planet's reflectance (or "albedo") and increase Ω toward 1. Any ETC that doesn't "go stellar" for its power, or wants to exceed an Ω of 1, must either moderate its power consumption or migrate to another planet as its non-stellar power sources overheat the planet.

Global planetary warming sets a fundamental limit on the power a civilization can consume. This phenomenon also provides a potential way to find an ETC — from its waste heat radiation. Earth-based researchers can use any residual reflected light from the planet to learn about the geographic variation of its surface. With sensitive new technology, we can improve on Dyson's idea and look for the heat from advanced alien cities as they rotate in and out of view of Earth — even with a telescope that couldn't otherwise directly image ETC cities from Earth.

Humans' global power consumption is growing by about 2.5 percent per year, even though the world's population is growing at less than half this rate.

We've seen on our planet that civilizations tend to cluster geographically. Populations on Earth concentrate into urban centers, and we expect ETCs to follow the same trend. The geography of a planet and the need for efficient agricultural and urban land use forces civilizations to clump. Although direct images of an ETC aren't possible with any foreseeable telescope, the clustering is detectable. From Earth, we can see the radiated ETC heat as a time variation from the rotational and orbital motions of the planet around its host star as alien cities rotate onto the side of the planet facing Earth.

The heat's source

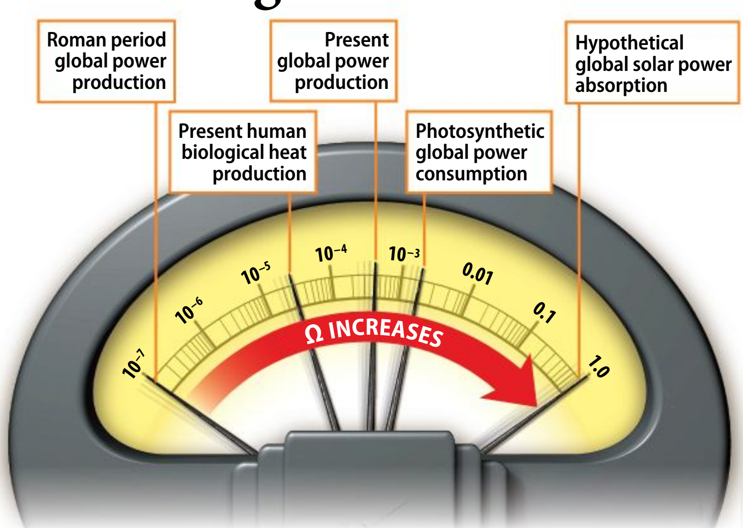
Astronomers study changes in a star's brightness to learn about, for example, "starspots" on its surface. Analogously, scientists can study extrasolar planets' brightnesses to investigate their surfaces as they rotate (unless the planet's spin aligns with our line of sight). Such time-varying brightness signals are observable with ground-based telescopes and could tell us about clumpy heat sources on the planet.

Numerical simulations suggest that measurements of a planet's brightness variations in both visible and infrared radiation make it possible to "see" an ETC. A large infrared-sensitive telescope could observe even those civilizations that utilize 1 percent of the total solar power they intercept. By combining visible and infrared observations of the planet, we can separate the signature of the ETC from natural variations (due to geography) on the rotating planet's surface.

Unlike natural planetary heat sources (like volcanoes) and absorbers (like clouds), a civilization's thermal footprint is likely to have a temperature only slightly higher than the planet's average. The laws of thermodynamics tell us that the most usable power (for example, to heat alien buildings, run light bulbs, or operate computers) occurs when the waste heat is returned to the planetary environment at temperatures close to ambient. The ETC thermal signal may be obscured by "noise" from the planet's natural radiation, but specific measurements could help us identify it. For

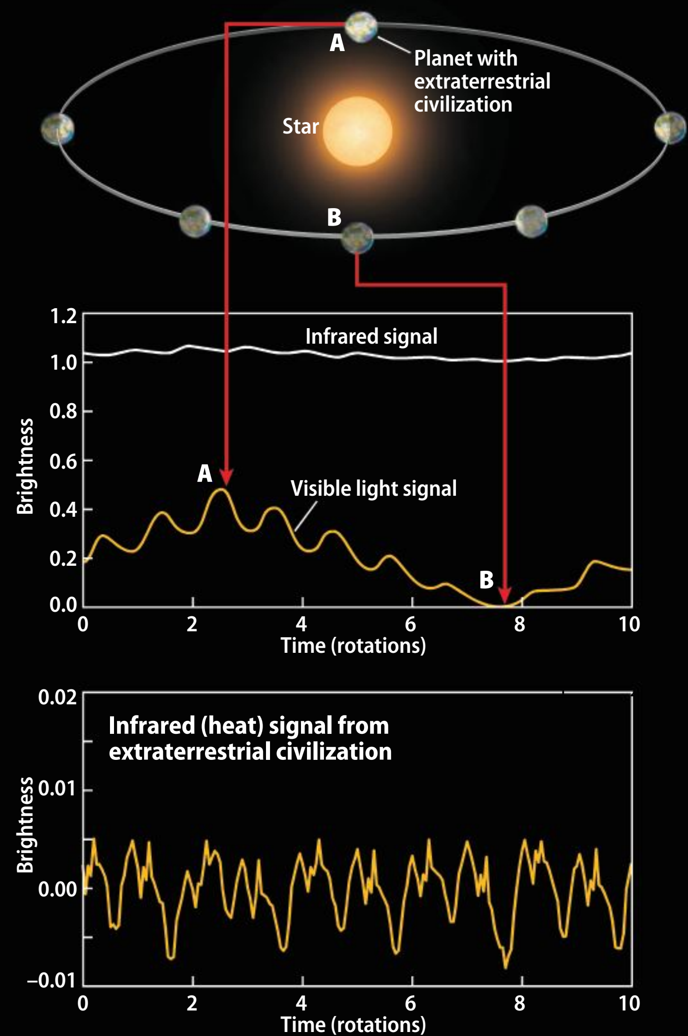
An advanced extraterrestrial civilization that uses all of the power its planet and moon intercept from its star is illustrated here. (The planet is at the right; the moon at the left.) Because such an alien technology would use almost all of its incoming radiation, the planet and the moon would have a very low optical brightness. DARYA RIOS

Power usage



This diagram illustrates the ratio Ω of a global civilization's power production to the amount of stellar energy its planet collects. The total power produced during Roman times is far less than it is today, which is less than a hypothetical civilization that uses all of the power its planet intercepts from its star. ASTRONOMY: ROEN KELLY, AFTER JEFF R. KUHN

Uncovering ET's signal



An exoplanet with an intelligent civilization — similar to humans — that uses 1 percent of the energy it receives from its star shows its presence in varying infrared and visible light signals. This simulation shows how scientists would tease the alien heat signal out of observations. *ASTRONOMY*: ROEN KELLY, AFTER JEFF R. KUHN

example, with infrared data at two wavelengths, we could distinguish the civilization's thermal signal from other natural heat signatures. Measurements like these would reveal the distinguishing emission profile of such hotter or colder natural radiation noise.

The targets

Nearby Earth-like exoplanets with liquid water are arguably the most likely to harbor life that we might eventually communicate with and learn from. Because such HZ planets in Sun-like star systems lie close to their stars (roughly the Earth-Sun distance or less), we'll need the technology to resolve such small separations. These correspond to angles on the sky of about 50 to 800 milliarcseconds. (For comparison, Pluto's disk spans about 100 milliarcseconds.) The brighter exoplanet targets are those that are closer to their host stars or larger in diameter because they reflect more light. Thus, the brightest and most detectable civilizations in our team's census will live on planets orbiting cooler suns that are nearby. We'd like to target all the known stars within 60 light-years of Earth that are in a similar evolutionary phase to the Sun (those that fuse hydrogen to helium in their cores).

Measuring the signals from our stellar neighbors requires a telescope with two important qualities: It must be large to collect enough photons from the alien planet to reliably detect a civilization's heat, and it must be able to distinguish the optical and infrared signal of the planet from that of its nearby host star. The telescope also must be sensitive enough to distinguish between the faint thermal radiation from the extrasolar planet and that from Earth's warm environment.

Pushing the technology

A host star might be some 100 million times brighter than a planet within its HZ, so to distinguish the faint glow of a civilization requires a telescope and detector system that removes the glare of the star to see the orbiting extrasolar planet. In theory, a perfect telescope system places all of the captured light from a star into a pointlike image, but this doesn't happen in practice. Observers must cope with Earth's weather and atmosphere, which can blur the radiation and create what astronomers call "scattered light" glare that works against us by obscuring the faint exoplanet. To work around this problem, we use specialized adaptive optics and an instrument (a coronagraph) that removes additional light scattering called diffraction. Some groups are building adaptive-optics/coronagraph systems that are nearing the sensitivity to detect extrasolar planets just 1 in 100 millionth as bright as their host stars in the same field of view: SPHERE at the European Southern Observatory's Very Large Telescope in Chile and GPI attached to the Gemini South Telescope, also in Chile.

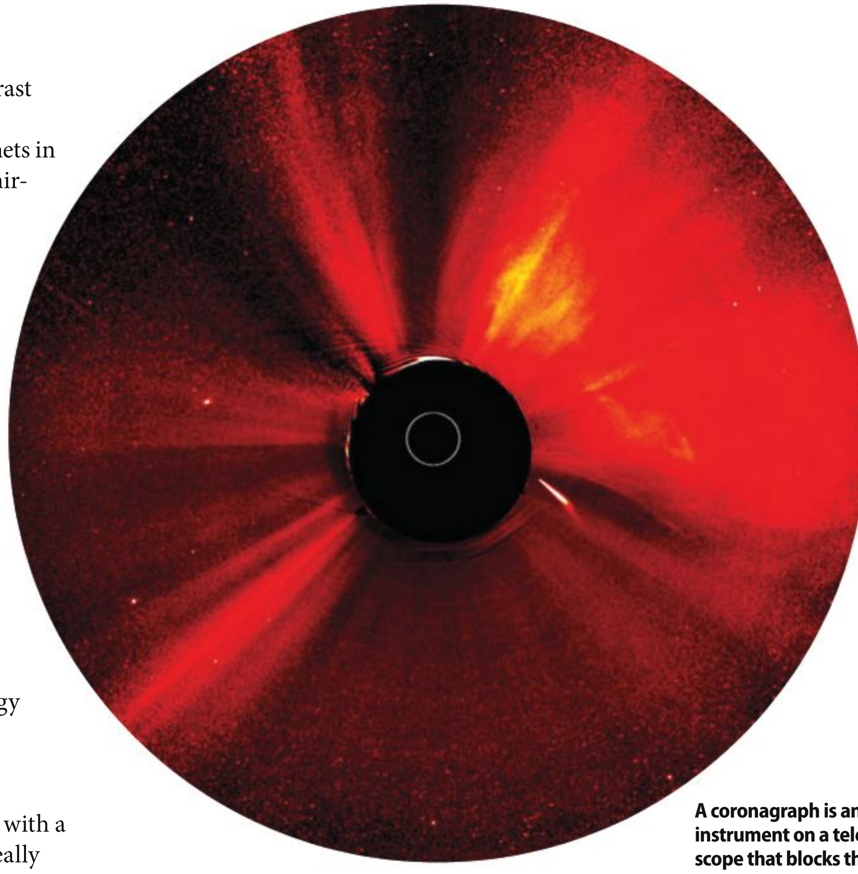
The smallest angle a telescope can resolve (called the "diffraction limit") decreases as the diameter of its primary mirror increases. To resolve and distinguish an HZ exoplanet from its star with a ground-based telescope requires two things: a large collecting area and an adaptive-optics system that reaches the diffraction limit of the scope while also correcting the blurring effect of Earth's atmosphere. The volume of space we can observe, and therefore the total number of stars we can sample, increases rapidly with the diameter of the telescope; this relationship follows the diameter cubed. So, the telescope's size is critical to this problem.

We'd like to target all the known stars within 60 light-years of Earth that are in a similar evolutionary phase to the Sun.

We know the locations and temperatures of most of the stars within 60 light-years of the Sun. This means we can accurately estimate the number of potential ETCs we might find based on the size of the telescope, the resolution of an

adaptive-optics system, and the instrument's contrast sensitivity at visible and infrared wavelengths.

As expected, the number of observable exoplanets in HZs increases rapidly when we factor in a larger mirror, greater coronagraph sensitivity, and a bigger planet diameter. If we want to detect at least 100 Earth-sized or slightly larger planets, we will need a telescope with a large diameter. The three largest infrared-sensitive scopes now in their planning stages (the Giant Magellan Telescope, the Thirty Meter Telescope, and the European Extremely Large Telescope) might be capable of detecting 10 HZ planets and, if scientists are lucky, perhaps one highly advanced ETC; they won't be large enough nor designed to minimize scattered light, so they won't make a dent in an ETC census. A telescope with a primary mirror about 250 feet (77 meters) in diameter, however, could find hundreds of Earth-sized or larger HZ planets, and perhaps dozens of ETCs, using a sensitive coronagraph — and the technology to build such an instrument exists.



A coronagraph is an instrument on a telescope that blocks the light from a star so that a nearby faint object is visible (and not washed out due to the star's glare). In this image, NASA's Solar TErrestrial RElations Observatory (STEREO) captured Comet SOHO 2143 that passed near the Sun on October 1, 2011, and was subsequently destroyed. NASA/STEREO

Expanding our horizons

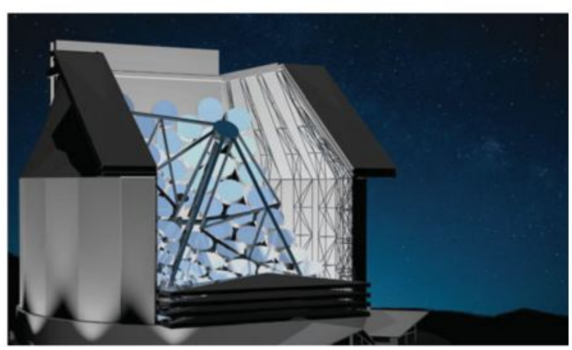
Yes, that's a huge telescope. Could an instrument with a mirror diameter nearly as big as a football field really be built? Such a colossus would have a light-collecting area an order of magnitude larger than the Giant Magellan Telescope, which is currently the large-telescope project furthest along.

A telescope with a primary mirror about 250 feet (77 meters) in diameter could find hundreds of Earth-sized or larger HZ planets . . . and the technology to build such an instrument exists.

A group of physicists, engineers, telescope builders, philanthropists, and businessmen — and the writers of this article — have spent two years studying exactly this question and concluded that building such a telescope is imminently doable, but it will require abandoning many of the assumptions and requirements researchers have made for the other huge scopes. For example, the "Colossus," as our team calls it, would not have a wide field of view like most giant telescopes, but instead would observe only a few arcseconds of the sky at a time. By decreasing the field of view, we can construct a telescope much larger than the current designs at less cost. This instrument also would use relatively few mirror elements — each one with the largest practical area possible — instead of hundreds of small segments. (Colossus' funding and location are as yet undetermined.)

Because of its narrow field of view, Colossus would observe starlike sources and would be ill-equipped to look at, for example, isolated distant galaxies. In addition to furthering our understanding of extrasolar planets and civilizations, we'd use this telescope for research topics like the study of stellar surfaces, black holes, and quasars — which are objects that appear smaller than 1 arcsecond across on the sky.

So, while the telescope required for our search for civilizations on other worlds doesn't exist yet, the technology does. We anticipate finding dozens of signals of life as we expand our understanding of the nearby cosmos. The Colossus would give us insight into whether civilization is a fragile development or if it is common. And we'd learn this without announcing ourselves.



THE COLOSSUS PROJECT

The Colossus telescope, shown here in this artist's rendering, would have a primary mirror nearly 250 feet (77 meters) wide. Scientists think this instrument would be able to resolve the infrared radiation that results from technologically advanced civilizations living on exoplanets within 60 light-years of Earth.

READ ABOUT WHAT WOULD HAPPEN IF ASTRONOMERS ACTUALLY DETECT ET SIGNALS AT **www.Astronomy.com/toc.**

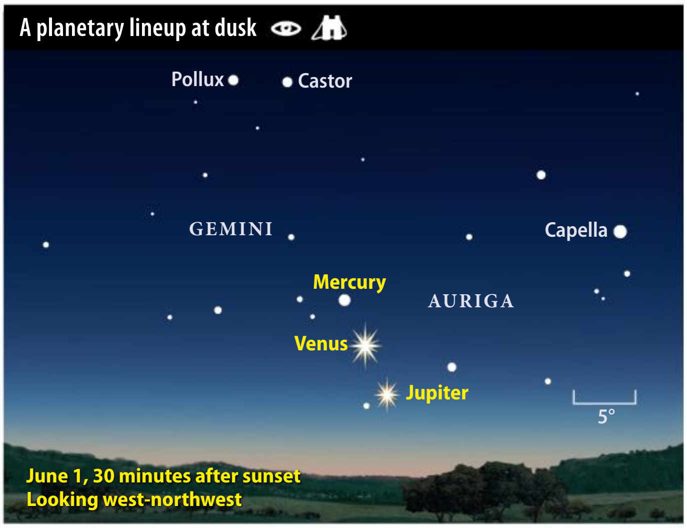
SKY THIS MONTH

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

June 2013: A trio of evening planets

Jupiter (top left) and Venus stood sentinel over Mercury (encircled by thin clouds at bottom right) in March 2012. These three bright planets have a return engagement in early June's evening sky. JAMIE COOPER



On June's first few evenings, Mercury, Venus, and Jupiter form a straight line in the twilight sky. Although Jupiter soon succumbs to the Sun's brilliance, Mercury and Venus remain close for most of the month. *ASTRONOMY*: ROEN KELLY

A pretty vista awaits viewers in early June when Mercury, Venus, and Jupiter line up in evening twilight. Although Jupiter and later Mercury become lost in the Sun's glow as the month progresses, Venus climbs higher and becomes more conspicuous. Once darkness falls, Saturn dominates the planetary scene from its perch high in the south. The early summer morning sky features Uranus and Neptune, which show up with optical aid.

Let's begin our tour in the western sky shortly after sunset. On June 1, Jupiter, Venus, and Mercury form a straight line angling to the upper left from twilight's brightest glow. The trio spans just 9°, roughly the width of a closed fist held at arm's length. Venus shines brightest at magnitude –3.8, followed by Jupiter (magnitude –1.9) and then Mercury (magnitude –0.3). Gemini's brightest stars, Castor and Pollux, come into view above the planets as twilight fades. The angular separation of the three solar system objects stretches out each evening as Jupiter drops toward the Sun while Venus and Mercury track across Gemini.

Although **Jupiter** has been a fixture in the evening sky since early winter, its time in the spotlight is nearing an end. The giant planet disappears into the solar glare by June's second week. It passes on the far side of the Sun on the 19th. Our star actually occults Jupiter that day, an occasion that happens twice during the planet's 12-year orbit.

Meanwhile, **Mercury** is heading toward its peak evening altitude for 2013. On June 8, it stands 5° to Venus' upper left, a degree more separation than on the 1st. Mercury then sets nearly two hours after the Sun, although it has faded to magnitude 0.2. When viewed through a telescope, the planet shows a growing disk with a waning phase. During June's first week, its size increases from

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

RISING**MOON**

A strikingly out-of-round lunar crater

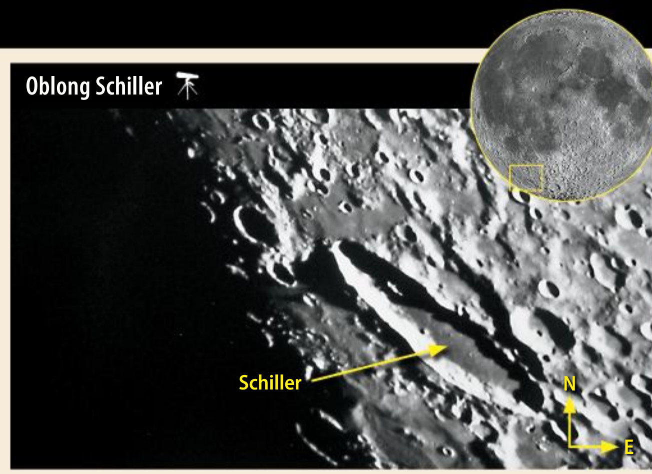
Look near the southwestern limb of a waxing gibbous Moon, and an arresting shoeprint-shaped impact feature will grab your attention. The Sun lights up Schiller on June 19, a few days before Full Moon. The crater's mostly flat floor and strongly elliptical shape first catch the eye. Although even circular craters appear oval when close to the Moon's limb, an effect called foreshortening, Schiller seems squashed twice as much as any other in the area.

Until a few decades ago, lunar observers were left scratching their heads trying to explain its form. But research into high-velocity impacts showed that single projectiles hitting at grazing angles can produce some unusual craters, including ones like Schiller. Well after the impact, lava welled up through crustal fractures to form the smooth floor. Messier A in Mare Fecunditatis is the poster child for such low-angle impacts.

To the northeast of Schiller, it's hard to miss the complex elliptical crater Hainzel. But look closely and you can figure out that separate impacts created it. The northwestern part is a roughly circular feature with a classic central peak. The southeastern section appears to have formed later because its floor better matches the texture and albedo of the overlapping area. Hainzel's southern component came first. You can tell because the other two overlay it and its rim appears softer from long-term bombardment.

When you're done here, look at Aristarchus in the Moon's northern third. When Earth's atmosphere is turbulent, refraction effects can make this crater appear to be outgassing.

Oblong Schiller



It's hard to miss the crater Schiller near the Moon's southwestern limb because it is 2.5 times longer than it is wide. *CONSOLIDATED LUNAR ATLAS/UA/LPL; INSET: NASA/GSFC/ASU*

6.6" to 7.6" while its phase dwindles from 60 percent to 45 percent lit.

A slim crescent Moon passes 6° south (lower left) of Mercury on June 10. Two days later, with the Moon some 25° away, the inner world reaches greatest elongation. It then lies 24° east of the Sun and appears 12° high 30 minutes after sunset. Although the planet has dimmed slightly, to magnitude 0.4, it still shows up nicely in the twilight.

By the time Mercury slides 2° south of **Venus** on June 20, the former glows at magnitude 1.2 — 100 times fainter than its neighbor. A wide-field telescope shows both planets together. Mercury appears 10" across and only 23 percent illuminated. Venus displays a fat gibbous phase on a disk just 1" wider than Mercury's.

Venus maintains its brilliance throughout June as it slowly gains altitude. It forms a straight line with Castor and Pollux on June 25, the same

— *Continued on page 42*

METEORWATCH

A shower of mystery

Although June is typically a quiet month for meteors, three experienced observers saw a flurry of activity June 11, 1930. The witnesses recorded meteors from a radiant in the constellation Delphinus, near the 4th-magnitude star Gamma (γ) Delphini.

Despite decades with no reported activity, meteor expert Peter Jenniskens of the SETI Institute predicts 2013 could see a return. His best estimates have a peak occurring June 11 at about 4:30 A.M. EDT. This timing is ideal for early morning viewing from the United States. The radiant then lies high in the sky, and the crescent Moon sets before midnight.

Jenniskens hasn't made any predictions about the level of activity or how bright the meteors might be, but the one sure thing is that if you don't watch June 11, you will never know. Astronomers at the International Meteor Organization (www.imo.net) would like to hear from anyone who carefully records their meteor observations that morning.

Gamma Delphinid meteors

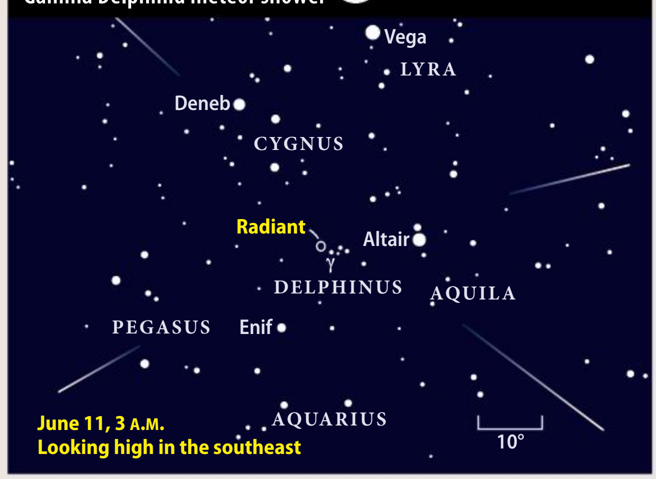
Active Dates: unknown

Peak: June 11

Moon at peak: Waxing crescent

Average rate at peak: unknown

Gamma Delphinid meteor shower



Skygazers could be in for a treat June 11, when a virtually unknown shower could produce a brief flurry of meteors. *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT Full Moon on June 23 occurs 20 minutes after the closest perigee of the year, making this the largest Full Moon (33.5' across) of 2013.

STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight June 1

11 P.M. June 15

10 P.M. June 30

Planets are shown at midmonth

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless magnified

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

JUNE 2013

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

3 The Moon passes 4° north of Uranus, 4 A.M. EDT

7 Neptune is stationary, 2 P.M. EDT

8 New Moon occurs at 11:56 A.M. EDT

9 The Moon is at apogee (252,579 miles from Earth), 5:40 P.M. EDT

10 The Moon passes 5° south of Venus, 7 A.M. EDT

The Moon passes 6° south of Mercury, 7 P.M. EDT

12 Mercury is at greatest eastern elongation (24°), 1 P.M. EDT

SPECIAL OBSERVING DATE

12 For Northern Hemisphere observers, Mercury appears at its highest in the evening sky for 2013.

13 Asteroid Juno is stationary, 9 A.M. EDT

16 First Quarter Moon occurs at 1:24 P.M. EDT

18 The Moon passes 0.1° north of Spica, 4 P.M. EDT

19 Jupiter is in conjunction with the Sun, noon EDT

The Moon passes 4° south of Saturn, 1 P.M. EDT

20 Mercury passes 1.9° south of Venus, 2 P.M. EDT

21 Summer solstice occurs at 1:04 A.M. EDT

22 Venus passes 5° south of Pollux, 9 P.M. EDT

23 The Moon is at perigee (221,824 miles from Earth), 7:12 A.M. EDT

Full Moon occurs at 7:32 A.M. EDT

25 Mercury is stationary, 7 P.M. EDT

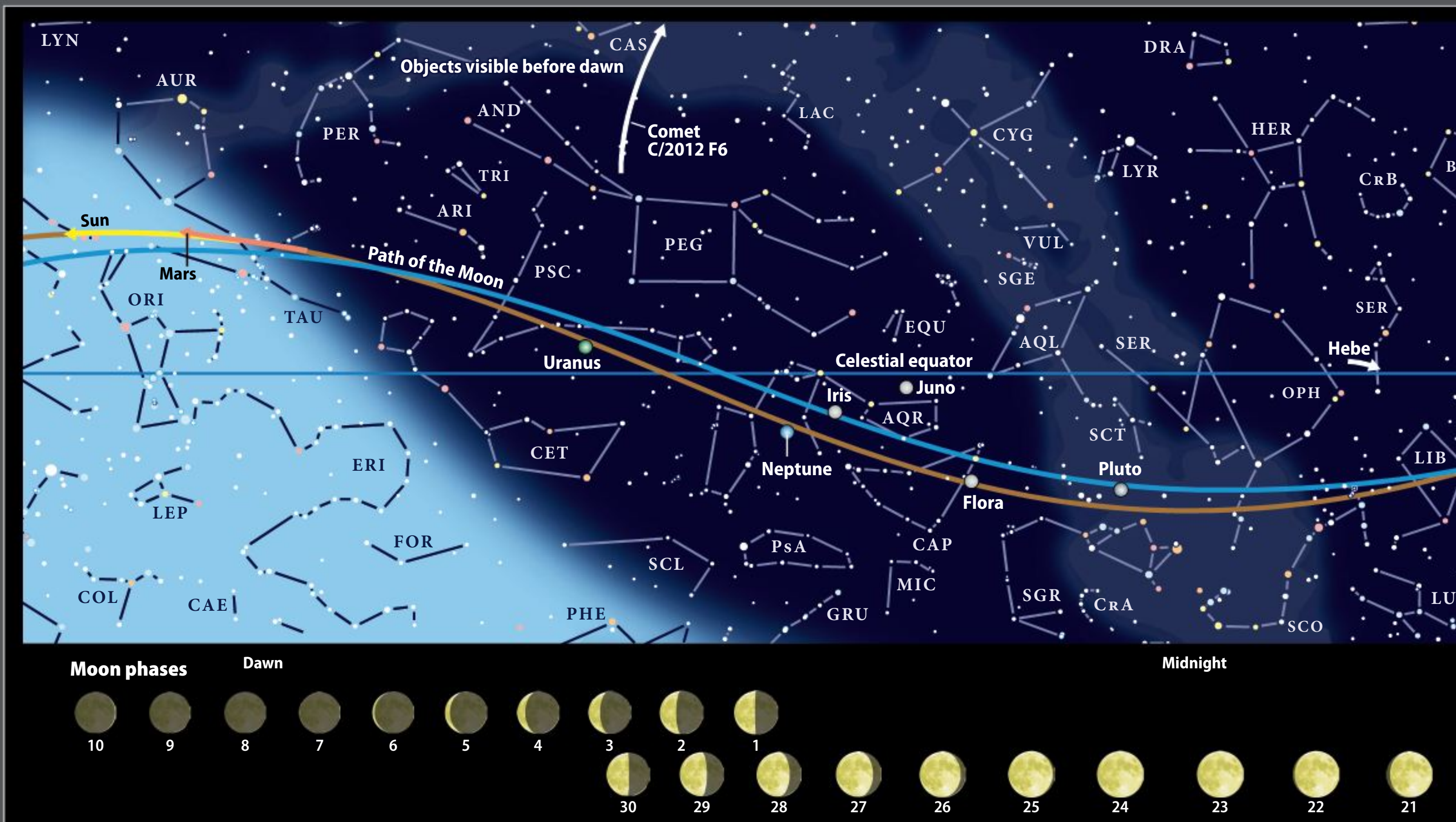
27 The Moon passes 6° north of Neptune, 5 P.M. EDT

30 Last Quarter Moon occurs at 12:54 A.M. EDT

The Moon passes 4° north of Uranus, 11 A.M. EDT

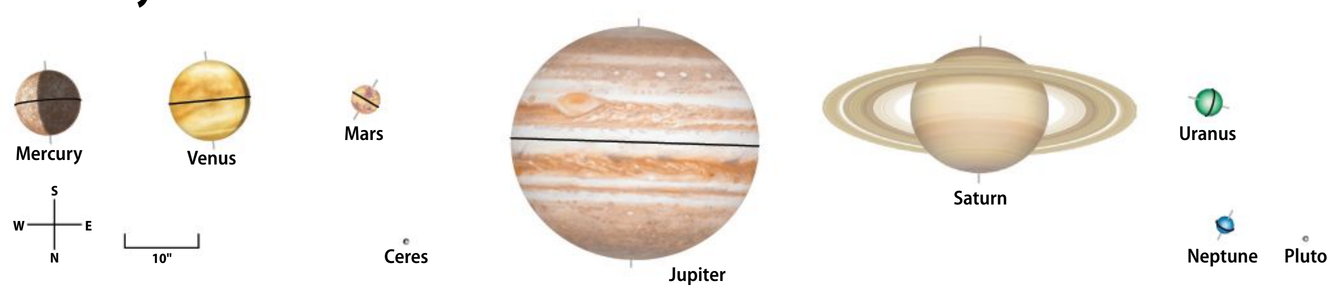
BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT www.Astronomy.com/starchart.

The planets in June 2013



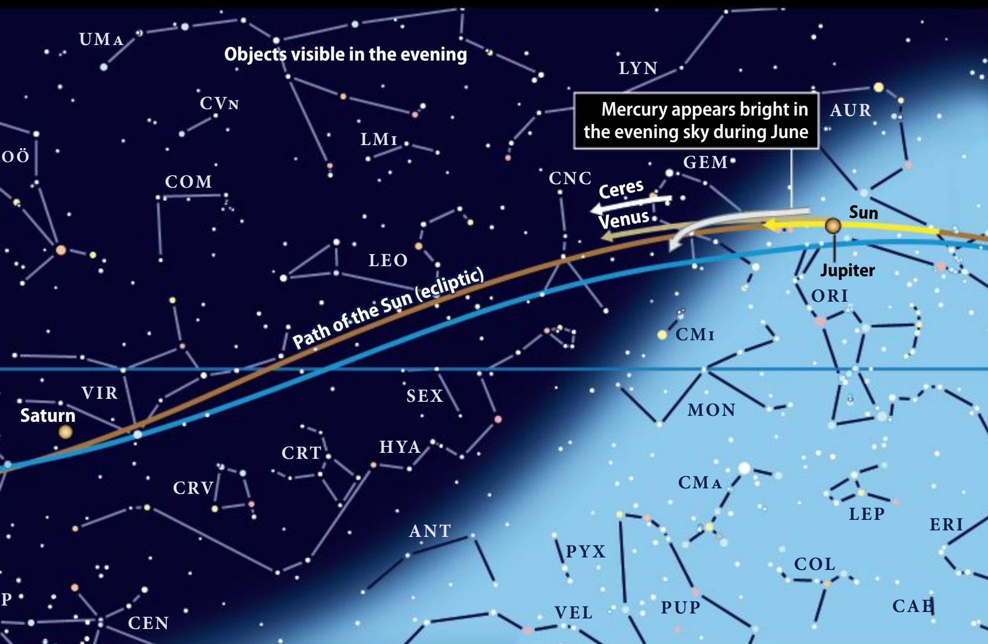
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.

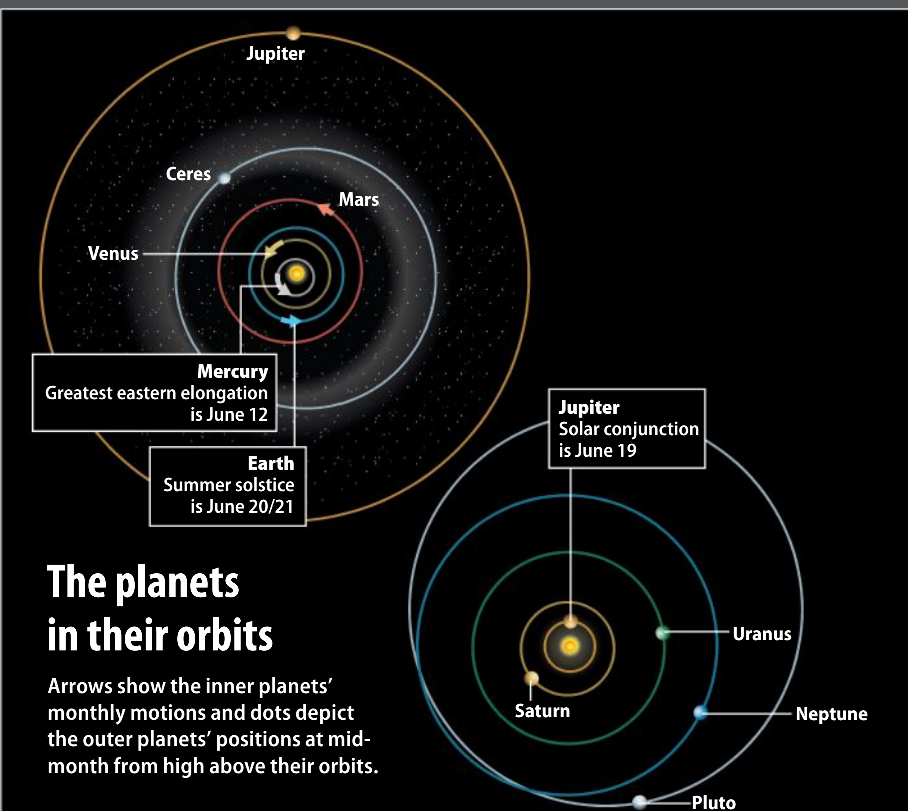


Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	June 15	June 15	June 30	June 15	June 1	June 15	June 15	June 15	June 15
Magnitude	0.6	–3.8	1.5	8.8	–1.9	0.4	5.9	7.9	14.0
Angular size	8.6"	10.6"	3.8"	0.4"	32.3"	18.2"	3.5"	2.3"	0.1"
Illumination	34%	93%	99%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.782	1.575	2.454	3.360	6.094	9.136	20.339	29.644	31.482
Distance (AU) from Sun	0.440	0.718	1.517	2.572	5.114	9.834	20.048	29.985	32.455
Right ascension (2000.0)	7h18.4m	7h02.9m	5h18.8m	7h59.7m	5h34.2m	14h14.6m	0h44.9m	22h29.0m	18h44.7m
Declination (2000.0)	22°59'	23°58'	23°29'	26°50'	23°03'	–10°47'	4°04'	–10°14'	–19°47'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.



To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

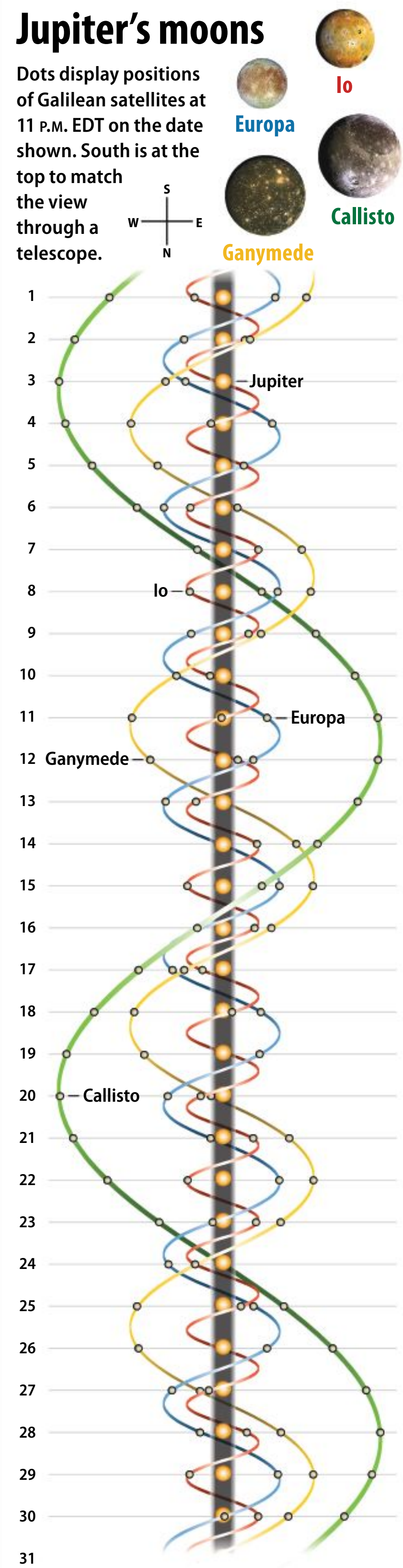


The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

— *Continued from page 37*

WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (northwest)	Saturn (southwest)	Mars (northeast)
Venus (northwest)		Uranus (east)
Jupiter (northwest)		Neptune (southeast)
Saturn (south)		

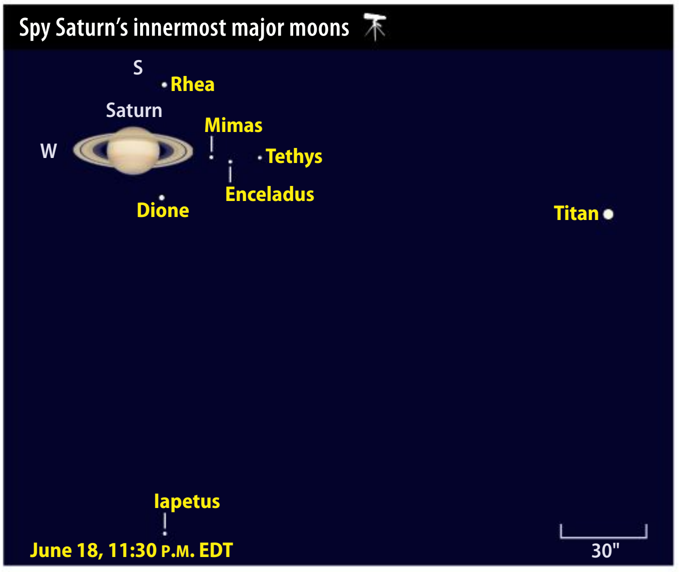
day it crosses from Gemini into Cancer.

As dusk settles in during June, **Saturn** stands nearly halfway to the zenith in the southern sky. It lies in eastern Virgo, where 4th-magnitude Kappa (κ) Virginis will remain its constant summer companion. Saturn lies 1.2° southeast of this star June 1. The gap closes to 0.4° — less than the Full Moon's width — by month's end. Saturn fades slightly in June, from magnitude 0.3 to 0.5, as it slowly pulls away from Earth.

Although the ringed world is great for naked-eye viewing this month, it stands alone among solar system objects for those with telescopes. The magnificent rings are easy to see through any instrument. They span 41" at midmonth and tilt 17° to our line of sight. They wrap around a disk that measures 18" across the equator and some 10 percent less through the poles.

The Saturn system holds more than 60 moons, of which seven glow brightly enough to show up through moderate-aperture scopes. The brightest, 8th-magnitude Titan, orbits Saturn every 16 days. You can find it due north of the planet the night of June 15/16 and due south the nights of June 7/8 and 23/24.

Saturn's outermost major moon, Iapetus, lies 9' west of the planet June 1, when it shines at 10th magnitude. It dims by a full magnitude by the time it passes 2.5' north of Saturn on the 18th and 19th. It appears fainter then because its ice-covered hemisphere is rotating out of view. When Iapetus reaches greatest eastern elongation in July, it will glow at 12th magnitude.



It's always a challenge to see Mimas and Enceladus near Saturn's rings, but viewers have a good opportunity the night of June 18/19. The planet's other bright moons conveniently lie nearby. *ASTRONOMY*: ROEN KELLY

COMETSEARCH

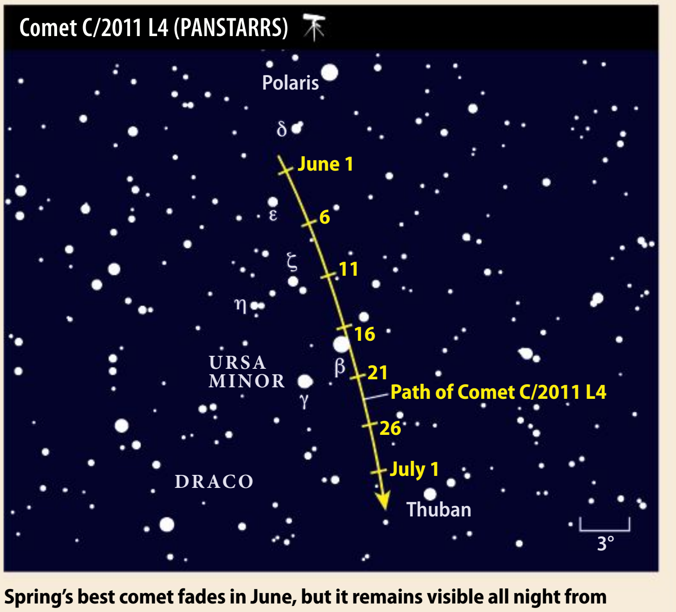
Spring's bright visitor bids a long farewell

As it recedes from the heat of the Sun toward its home in the frigid Oort Cloud, spring's lovely Comet C/2011 L4 (PANSTARRS) releases less dust to scatter sunlight back in our direction. Coupled with the comet's increasing distance from both its light source and Earth, the fuzzy snowball should fade to 9th or 10th magnitude during June.

On the positive side for Northern Hemisphere observers, the comet remains visible all night because it lies near the North Celestial Pole. It slides past Polaris and its cosmic security, the so-called guard stars Kochab and Pherkad (Beta [β] and Gamma [γ] Ursae Minoris, respectively).

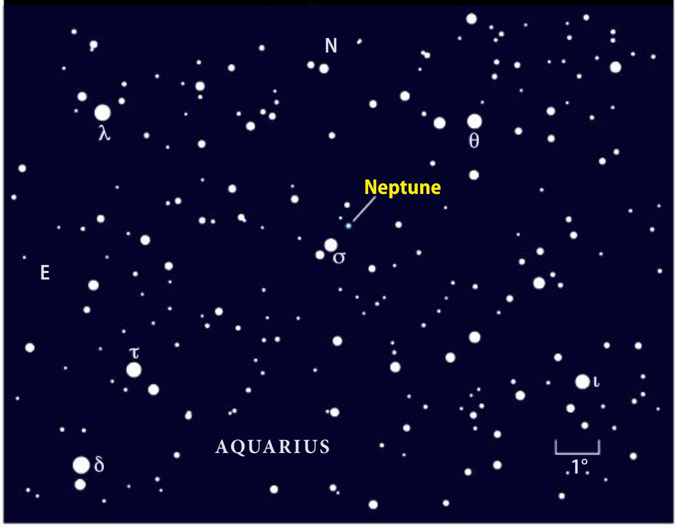
The only deep-sky objects in this region are faint galaxies, so you won't misidentify the grayish cotton ball in 4-inch or larger telescopes. But it will be pretty tough to see PANSTARRS from the suburbs through the veil of light pollution. And because it lies nearly due north, you should scout out a new dark-sky site north of your city and skip the more common ones to the south. Don't assume that the comet will be easy to bag from June 16 to 19 when it passes within 1° of 2nd-magnitude Kochab. Interference from a waxing gibbous Moon will make that a challenging observation.

To help maximize the contrast between the comet and sky, push the magnification to 120x or more and use a dark hood over your head to keep out stray light and allow your eye to dark adapt as much as possible. PANSTARRS should look somewhat similar to NGC 3077, the satellite galaxy of the bright spiral M81 roughly 20° away in Ursa Major. Both should appear brighter in the middle with diffuse edges, although the sunward-facing edge of the comet should appear sharper.



Spring's best comet fades in June, but it remains visible all night from mid-northern latitudes as it slices through Ursa Minor. *ASTRONOMY*: ROEN KELLY

Neptune returns to view



The outermost major planet stands well above the southeastern horizon before dawn this month. The stars of central Aquarius serve as handy guides for locating it. *ASTRONOMY*: ROEN KELLY

Three additional moons shine at 10th magnitude and show up easily through 4-inch scopes, at least when they're not too near the bright planet. Tethys, Dione, and Rhea circle Saturn on orbits inside Titan's. They take 1.9, 2.7, and 4.5 days, respectively, to revolve around the ringed world.

You'll need an 8-inch scope to spy 12th-magnitude Enceladus. Its 1.4-day orbit keeps it within 35" of Saturn's center all month, less than twice the radius of the bright rings. You'll need to increase the aperture another couple of inches if you hope to see Mimas. This tiny moon glows a magnitude fainter than Enceladus and flits around Saturn in just 23 hours, so it always hovers close to the outer edge of Saturn's rings.

The best time to hunt for the two inner moons comes when they lie farthest from the rings. The night of June 18/19 provides a great opportunity because they both reach greatest eastern elongation within a half-hour or so of each other. Titan and Tethys also lie east of the planet that night to help guide your eye to the inner worlds, and Iapetus is nicely placed due north of Saturn.

Neptune rises around 1:30 A.M. local daylight time June 1 and some two hours earlier on the 30th. It shows up best shortly before twilight begins, when it lies about 30° high in the southeast. Still, you'll need some optical aid to spot the magnitude 7.9 planet.

The ice-giant world remains nearly stationary against the relatively barren region of central Aquarius. You can find it 0.6° northwest of 5th-magnitude Sigma (σ) Aquarii. To locate the area, start with four 4th-magnitude stars that form a distorted square: Lambda (λ), Theta (θ), Iota (ι), and Tau (τ) Aqr. Then, draw two imaginary diagonal lines across this figure. Neptune and Sigma lie near the intersection of these lines. When viewed through a telescope, the planet shows a disk that spans 2.3" and has a noticeable blue-gray hue.

Uranus pokes above the eastern horizon around 3 A.M. local daylight time in early June and stands nearly 15° high as twilight begins. The magnitude 5.9 planet spends the month in Pisces about 4° south of 4th-magnitude Delta (δ) Piscium. A waning crescent Moon lies nearby on the 3rd, occulting the star across much of North America. Uranus shows up through binoculars even with the Moon's proximity. A telescope reveals Uranus' 3.5"-diameter disk and blue-green color.

At the end of June, you might catch a brief glimpse of **Mars** low in morning twilight. The Red Planet rises around 75 minutes before the Sun and climbs just 7° high a half-hour before sunrise. Use binoculars to glimpse the magnitude 1.5 world.

LOCATING**ASTEROIDS**

Ceres treks in proximity to Pollux

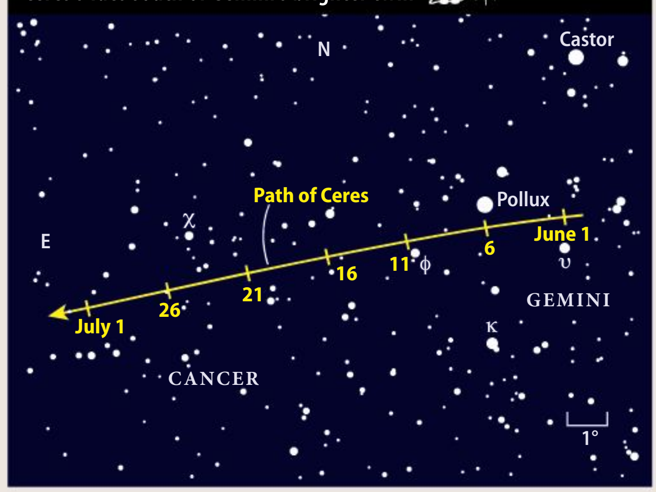
Early June provides a perfect opportunity to star-hop to an asteroid. Just set your scope on 1st-magnitude Pollux and you're almost on top of Ceres. If you can't remember which of Gemini's twins is which, noted astronomy author Ken Hewitt-White suggests this mnemonic: "Castor is closer to Capella, Pollux closer to Procyon."

Because Ceres sets early, start searching about an hour after sunset. From June 5 to 7, the king of the asteroid belt lies less than 1° south of Pollux. Ceres glows at magnitude 8.8, and only one star in its immediate vicinity appears brighter, at magnitude 8.4. For weekend nights on either side of the asteroid's close approach to Pollux, star-hopping requires a bit more care and a couple extra minutes.

During June's second half, 595-mile-wide Ceres crawls across the stardust of Cancer the Crab's celestial beach. The background stars here appear much the same as the dwarf planet. To make a positive ID, quickly sketch your telescope's field of view and return a night or two later — the dot that shifted is Ceres. It often can be more satisfying to see the sky change than to take for granted a tick mark on a finder chart.

By June's close, Ceres dips below the northwestern horizon just before twilight ends. It will pass behind the Sun from our vantage in August and return to the morning sky in late September.

Ceres slides south of Gemini's brighter twin



Magnitude 8.8 Ceres passes within 1° of 1st-magnitude Pollux, Gemini's brightest star, during June's first week. The largest asteroid crosses into Cancer at midmonth. *ASTRONOMY*: ROEN KELLY

GET DAILY UPDATES ON YOUR NIGHT SKY AT www.Astronomy.com/skythisweek.

PLANETARY TOUCHDOWN

Q: HOW DO MISSION DESIGNERS KNOW AT WHAT ANGLE TO LAND ON AN ASTRONOMICAL BODY SUCH AS THE MOON, MARS, OR EARTH?

***Matthew Schewe,** Eden Prairie, Minnesota*

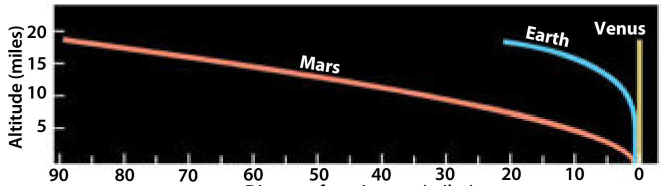
A: A planetary body's atmosphere controls the angle during entry, descent, and landing from a combination of the gravitational force and atmospheric drag. Venus and Earth have thick atmospheres, so drag slows the entry capsule to the point where it falls straight down to the surface the last few miles. For Earth, this vertical descent occurs at an altitude of about 6 miles (10 kilometers), while for Venus, with its much thicker atmosphere, it occurs at about 35 miles (60km). A craft will deploy parachutes to provide a soft landing — not to control the angle.

The atmosphere of Mars, however, is so thin that vertical descent never occurs. The Mars Exploration Rover Opportunity experienced a perfect example of this in 2004: A parachute deployed at an altitude of about 4.7 miles (7.5km) to slow the entry capsule for a softer landing, but this equipment had little effect on the landing angle. The Mars Science Laboratory landing on August 6, 2012, incorporated a guidance system for a vertical touchdown to place the Curiosity rover softly on the surface.

Because the Moon has no atmosphere, all lunar landings depend on guidance rockets; one example of this process is Neil Armstrong's heroic manual guidance of the Apollo 11 Lunar Module *Eagle* on July 20, 1969.

John Anderson
Jet Propulsion Laboratory (Retired), Pasadena, California

Comparing landing angles



Comparing typical trajectories for Mars (red), Earth (blue), and Venus (yellow) during the descent from an altitude of nearly 20 miles (32 kilometers) to the surface of the planet shows how an atmosphere's thickness affects the landing angle. *ASTRONOMY*: ROEN KELLY, AFTER JOHN ANDERSON

Q: HOW MUCH COLOR SHOULD I BE ABLE TO SEE IN SKY OBJECTS THROUGH A 10-INCH TELESCOPE?

Dennis Holt
Concordia, Kansas

A: Unfortunately, when you look at distant galaxies and nebulae, you won't see much color through your telescope. That's because you're viewing objects that are too faint to trigger your eyes' color receptors. (This is the same reason why on Earth we see lots of color in the daytime but not much at night.)

However, two classes of celestial objects — double stars and planetary nebulae — break this rule. The reason is their sizes. Stars are point sources, and planetaries typically measure less than 1 arcminute across. (As a comparison, the Full Moon spans 31 arcminutes.) So although they're not really all that bright, their light concentrates over a small area. In astronomical terms, their surface brightnesses are high. The table above ("Color test") provides 10 colorful objects to observe.

Michael E. Bakich
Senior Editor

COLOR TEST

Here are five colorful double stars and five planetary nebulae in which you should see color; they are organized by group and then right ascension. You'll find the positions of all these objects using *Astronomy*'s interactive star atlas at www.Astronomy.com/stardome.

Object	Designation	Colors
Albireo	Beta (β) Cygni	Blue and gold
Achird	Eta (η) Cassiopeiae	Yellow and red
Al Rischa	Alpha (α) Piscium	Yellow and blue
Almach	Gamma (γ) Andromedae	Yellow and blue
Kaffaljidhma	Gamma Ceti	White and blue
The Little Gem	NGC 6818	Green
The Blue Flash	NGC 6905	Blue
The Saturn Nebula	NGC 7009	Blue-green
The Blue Snowball	NGC 7662	Blue
Cleopatra's Eye	NGC 1535	Blue

Q: IS IT POSSIBLE FOR A QUARK STAR TO EXIST?

Richard Hall
Charlotte, North Carolina

A: A quark is an elementary subatomic particle; three of them make up a proton or a neutron. Some scientists base the suggested existence of quark stars (which would be made of quarks instead of complete protons or neutrons) on a famous conjecture by the eminent Princeton physicist Ed Witten. He said the true ground state of matter (in the sense of the lowest energy per particle) consists of a mixture of roughly equal numbers of up, down, and strange quarks, with enough electrons thrown in to ensure that this soup is electrically neutral. Although scientists have never demonstrated this conjecture to be true, many theoretical astrophysicists have run with it, imagining the potential implications for the heavens.

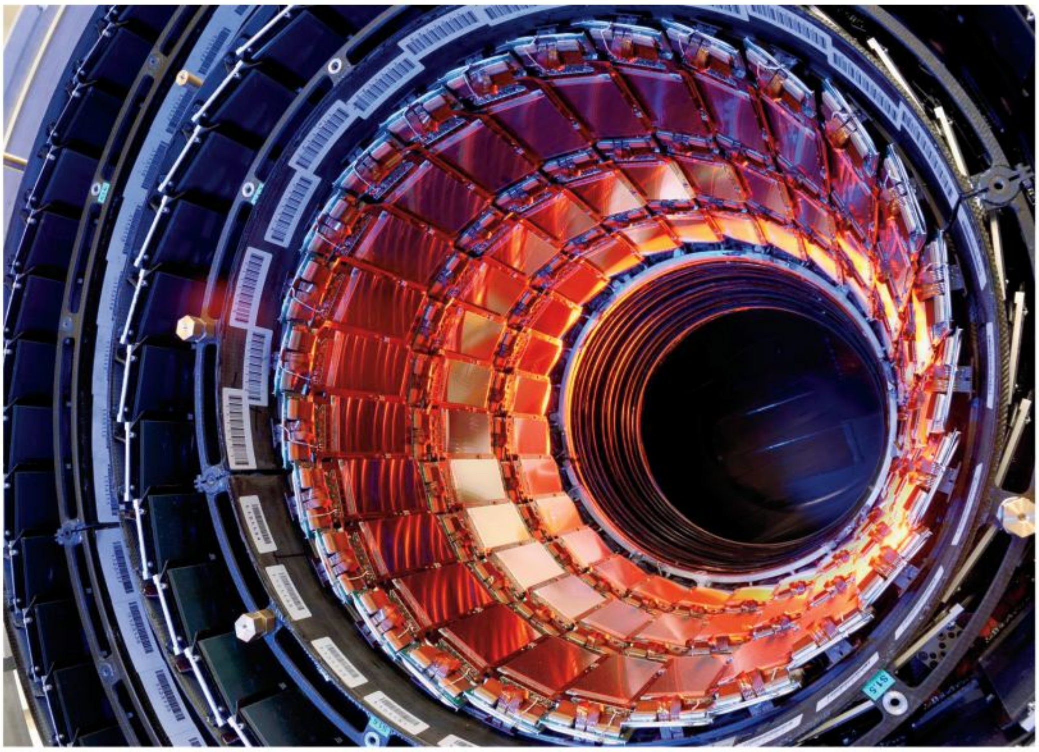
One resulting hypothesis is that certain unusual stars could be made entirely of such matter — hence the name "quark stars." Such objects likely would share many observational properties with neutron stars but, for example, would have no minimum mass (whereas neutron stars are likely more than 1.1 times the Sun's mass) and would generally be smaller than neutron stars of the same mass because they're denser.

There is currently no strong evidence that quark stars exist; however, some observations suggest they may.

For example, scientists using data from NASA's Chandra X-ray Observatory reported that the nearby neutron-star candidate RX J1856.5–3754 has an X-ray spectrum consistent with a source whose radius is between 2.4 and 5.1 miles (3.8 and 8.2 kilometers) — that's too small to be a neutron star. This observation prompted Jeremy Drake of the Smithsonian Astrophysical Observatory and colleagues to title their publication "Is RX J1856.5–3754 a Quark Star?" The general consensus among the astronomical community is "not particularly likely." This response is largely because of uncertainties in the assumptions that the authors made in their spectral analysis, and thus the object may not be as small as reported. Still, RX J1856.5–3754 is intriguing.

In summary, while we don't have strong evidence for quark stars' existence, there is still some possibility that they're out there but can't yet be unambiguously identified.

Victoria Kaspi
McGill University, Montreal



The silicon inner tracker of the Compact Muon Solenoid detector at the Large Hadron Collider contains some 66 million pixels to capture information about every particle that whizzes through. CERN/MAXIMILIEN BRICE

Q: HOW DO SCIENTISTS KNOW THAT THE PARTICLES REVEALED AFTER A PROTON OR LEAD ION COLLISION ARE DIFFERENT FROM EACH OTHER, SUCH AS QUARKS AND MUONS, AND NOT JUST SMALLER PIECES OF PROTONS OR LEAD IONS? (IF I WERE TO SMASH TWO LEAD BULLETS TOGETHER, THEY WOULD BREAK INTO SMALLER PIECES, BUT THEY WOULD STILL BE LEAD.)

David Kennedy
Aburndale, Florida

A: When particle accelerators collide protons or lead ions, they do so within special sections of an instrument that can capture fine details. These huge detectors are like giant digital cameras that take photographs of the outcome of each collision. (Researchers keep only a subset of these photographs, but that is another story.) These pictures record information about each outgoing particle produced in the collision.

Unlike photographs where the detector is the film's two-dimensional surface, particle detectors are thick and multilayered (i.e., three-dimensional), and the outgoing particles often pass though many (or all) layers of the apparatus and interact with those materials as they go. These interactions allow us to measure such properties as the charge, momentum, and energy of each of these particles. Furthermore, the many different systems in the detectors help us determine what type of particle it is. For instance, a muon is the only particle that can travel from the detector's center, where the collision occurred, to the outermost tracking layer; if we detect something in the outer region, it is a muon.

We need to measure as much about each collision as possible because they are complicated events, and piecing together exactly what happened is a challenging business. Only by measuring very precisely what each collision created can we determine if a Higgs boson, or some other new particle, was made.

When two bullets collide, the energy carried by individual particles within each bullet is rather small. But particles traveling within an accelerator carry enough energy that a collision will produce other particles. In fact, a typical collision of two protons makes hundreds of particles; lead ion collisions will make many more. At these high energies, the collision occurs between the sub-components of the protons — the quarks and the gluons — and the produced particles can be anything that the symmetries of nature allow. That means that energy, momentum, and charge must be preserved, but quantum mechanics theory allows any final state that conserves these properties. Some states are more likely than others, and it is our job to search for the more unlikely, and more interesting, ones, which requires these advanced detectors.

Patrick Fox
Fermi National Accelerator Laboratory, Batavia, Illinois

Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Explore the ULTIMATE PLANETARY NEBULA catalog

The Perek-Kohoutek catalog contains some of the smallest, faintest, and most enigmatic deep-sky treats.

text by Michael E. Bakich; celestial images by Don Goldman

PK 158+17.1 is also known as Purgathofer-Weinberger 1. It's a circular planetary with a diameter of 20' in the constellation Lynx.

Michael E. Bakich *is a senior editor of* Astronomy. **Don Goldman** *is the owner of Astrodon Filters in Roseville, California, and a dedicated astroimager.*

It's probably safe to assume many of our readers will recognize the name Luboš Kohoutek. Well, at least the last name. He is the Czech astronomer who discovered Comet C/1973 E1 (Kohoutek) in March 1973. This reasonably bright object (as comets go) became "the dud of the century" thanks to grandiose predictions (most notably by American astronomer Carl Sagan on *The Tonight Show Starring Johnny Carson*) of how brilliant it would become.

But do you know the name Luboš Perek? Another Czech astronomer, he collaborated with Kohoutek on *Catalogue of Galactic Planetary Nebulae*, which is the most famous compilation of such objects. The two published the first version of their catalog in 1967. Astronomers usually refer to it as CGPN (1967). Between 1978 and 1999, Kohoutek published six supplements to the catalog. The latest version, called CGPN (2000), contains 1,510 objects classified as galactic planetary nebulae up to the end of 1999.

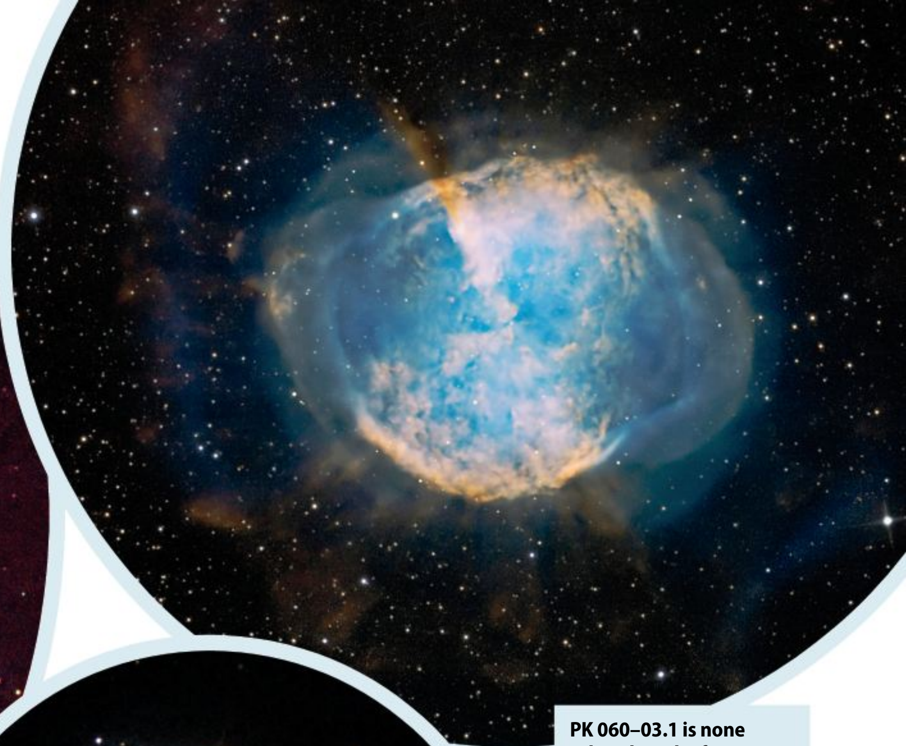
A bit of history

French comet hunter Charles Messier found the first planetary nebula — the Dumbbell Nebula (M27) in Vulpecula — in 1764. But it wasn't until January 1779 that French astronomer Antoine Darquier de

Luboš Perek, born in 1919, conducted research on high-velocity stars, mass distribution in the Milky Way, and the management of outer space. MASARYK UNIVERSITY

Luboš Kohoutek, born January 29, 1935, has discovered 75 asteroids and several comets, including C/1973 E1 (Kohoutek), the famous one named for him. NASA

PK 219+31.1 is also known as Abell 31 and Sharpless 2–290. It lies 2,000 light-years away in the constellation Cancer.



PK 060–03.1 is none other than the famous Dumbbell Nebula (M27) in Vulpecula, the first planetary nebula discovered. Charles Messier found it July 12, 1764.

PK 118–74.1 is better-known either as the Skull Nebula, NGC 246, or Caldwell 56. It lies in the constellation Cetus the Whale about 1,600 light-years from Earth.

Pellepoix described the Ring Nebula (M57), which he discovered, "… as large as Jupiter and [resembling] a planet which is fading."

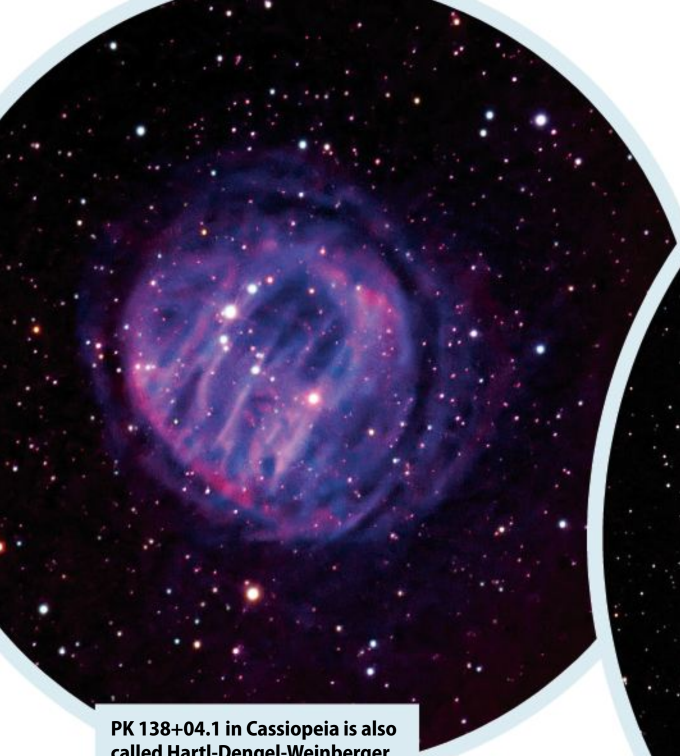
By the end of the 18th century, scientists knew of only 13 planetary nebulae. Observers in the 19th century added 65 more. American astronomer Heber D. Curtis compiled the first list of planetary nebulae in 1918, as part of *Publications of the Lick Observatory*, No. 13, Part III, pp. 55–74. It contained 102 objects.

The count grew under the observational scrutiny of Russian astronomer Boris Vorontsov-Velyaminov. His first catalog, which he produced with fellow Russian astronomer Pavel P. Parenago, appeared in 1931 and contained 121 planetary nebulae. Vorontsov-Velyaminov upgraded the catalog in 1948 to 288 entries and in 1962 raised the total to 591 entries.

Because different astronomers have proposed different ideas about the processes

PK 136+05.1 is the ultrafaint planetary Heckathorn-Fesen-Gull 1 in Cassiopeia. This object has attracted much attention because of its central star, which is the precataclysmic binary system V664 Cas.

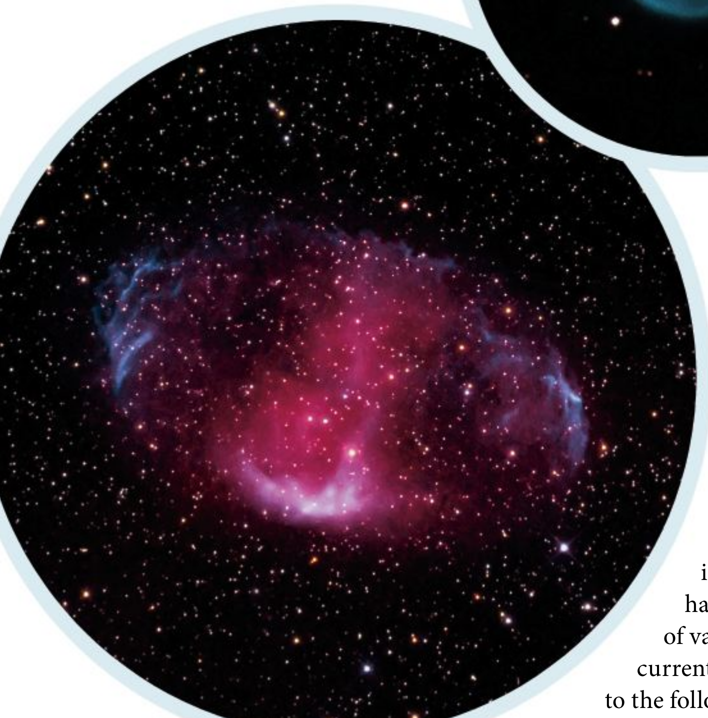
PK 283+25.1 is the Southern Owl Nebula in Hydra, so called because of its resemblance to the Owl Nebula (M97) in Ursa Major.



PK 138+04.1 in Cassiopeia is also called Hartl-Dengel-Weinberger 2 and Sharpless 2–200. It has a roughly circular central area featuring striations and a dark region surrounded by a thin gap and an outer bright halo with fine structure. The halo probably represents the edge of an expanded shell from an earlier expulsive event.

PK 072–17.1 is the large planetary Abell 74 in Vulpecula the Fox. This object's white dwarf central star has a temperature of 108,000 kelvin (194,000° Fahrenheit).

PK 047+42.1 is the Perek-Kohoutek designation for Abell 39, a spherical planetary in the constellation Hercules. This object has a diameter of 6 light-years and features a 0.3-light-year-wide bright rim.



PK 080–10.1 is Motch-Werner-Pakull 1, an evolved bipolar planetary 1,400 light-years from Earth in Cygnus the Swan. One of the sky's largest such objects, MWP 1 measures 13' by 9'.

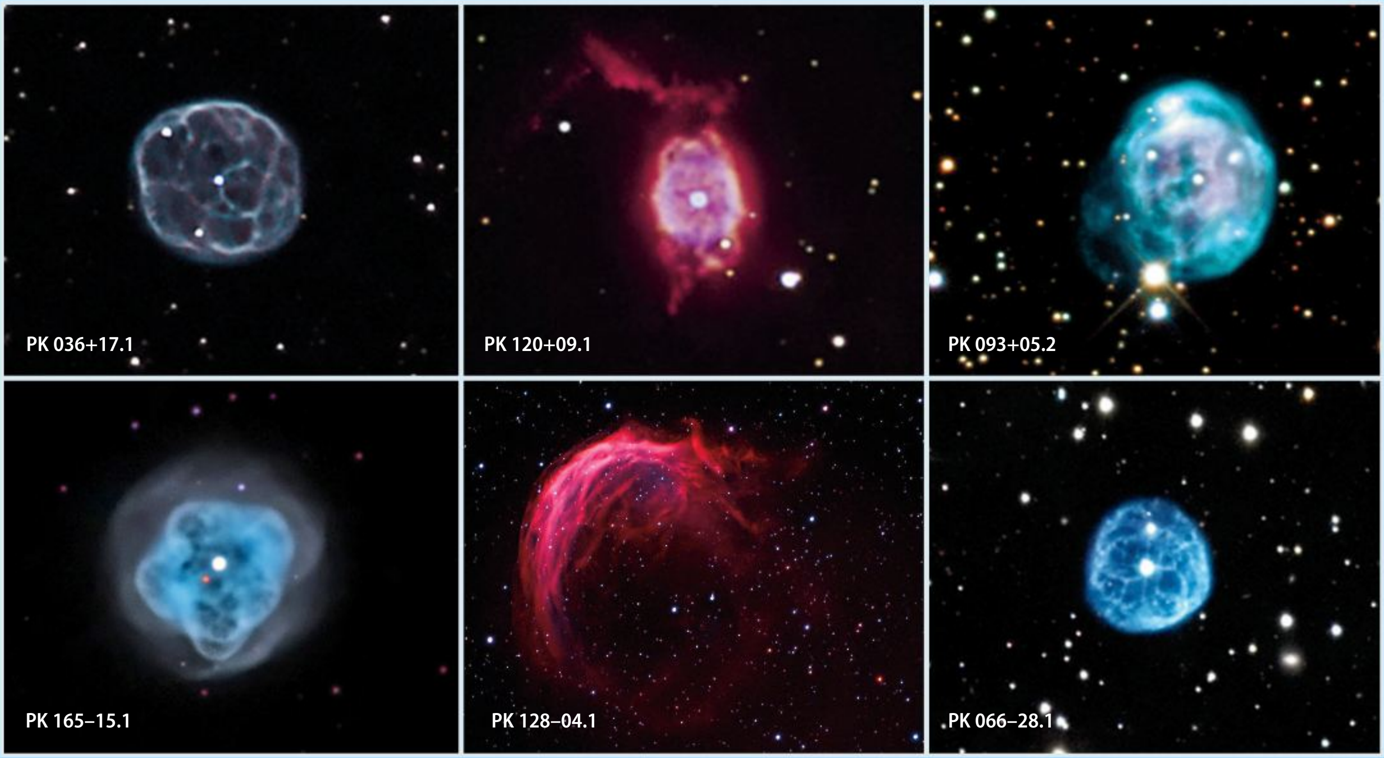
that constitute these enigmatic objects, Kohoutek addressed the issue when he produced CGPN (2000): "In order to answer the fundamental question 'what is a planetary nebula?' we have compared the properties of various objects considering the current review literature and came to the following conclusion: A planetary nebula is a mainly gaseous object (also containing dust) expanding from its hot central star of intermediate mass in a late evolutionary phase on the way between red giants and white dwarfs. The central stars ionize and illuminate the respective nebulae."

A word about numbering

For CGPN (2000), Kohoutek used the same numbering scheme he and Perek used in CGPN (1967). In it, the first of two sets of numbers up to three digits long is the galactic longitude, and the second set represents galactic latitude. Because latitude tops out at plus or minus 90°, this set may add a number after the decimal point. So, for example, the Bow-tie Nebula (NGC 40) in Cepheus is PK 120+09.1.

Within the data for CGPN (2000), however, Kohoutek recognized that many astronomers would use designations as adopted by the International Astronomical Union (IAU), so he added: "We also give … the IAU designations of galactic planetary nebulae recommended by IAU Commission 5 (Astronomical Nomenclature)." The IAU designation of NGC 40 therefore would be PN G120.0+09.8.

PK PLANETARIES FOR AN 8-INCH SCOPE



These six PK objects look great through medium-sized telescopes. The Perek-Kohoutek designations in the top row from left to right correspond to Abell 43, the Bow-tie Nebula (NGC 40), and the Fetus Nebula (NGC 7008). Those in the bottom row from left to right equal the Crystal Ball Nebula (NGC 1514), Sharpless 2–188, and NGC 7094.

Targets abound

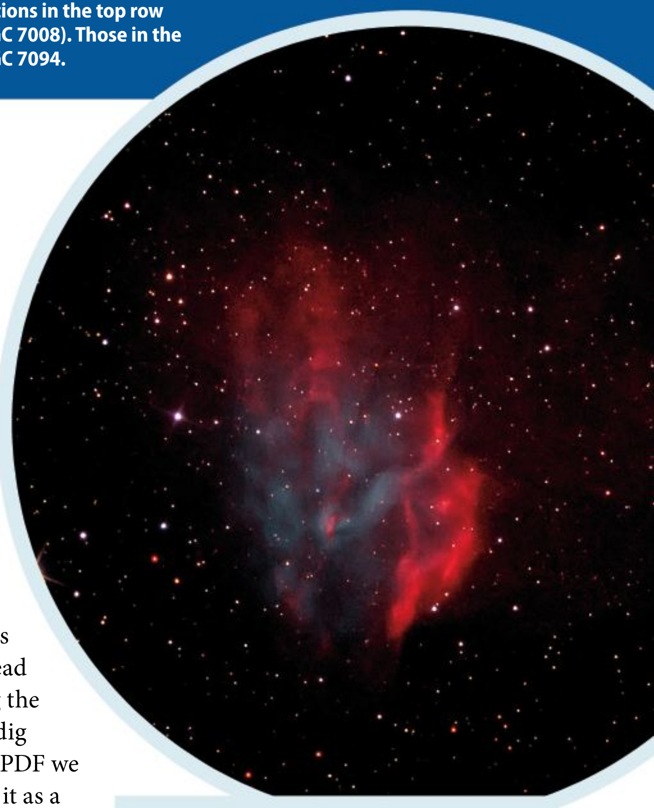
The Perek-Kohoutek catalog contains every notable planetary nebula in the sky, so, naturally, it features objects for observers with any size telescope. Through 4- to 8-inch instruments, first aim for the four bright planetaries in Charles Messier's catalog: the Dumbbell Nebula (PK 060–03.1), the Ring Nebula (PK 063+13.1), the Owl Nebula (PK 148+57.1), and the Mini Dumbbell Nebula (PK 130–10.1).

Your second tier of targets should still be relatively bright and perhaps offer a hint of color. Examples are the Double Bubble Nebula (PK 189+19.1); the Eskimo Nebula (PK 197+17.1); NGC 2348 (PK 231+04.2), which resides in open cluster M46; the Albino Butterfly Nebula (PK 234+02.1); the Eight-Burst Nebula (PK 272+12.1); the Ghost of Jupiter (PK 261+32.1); the Blue Planetary (PK 294+04.1); the Turtle Nebula (PK 043+37.1); and the Bug Nebula (PK 349+01.1) in Scorpius.

Owners of 14-inch or larger telescopes surely will want to challenge themselves by hunting even fainter quarry. Try for the Medusa Nebula (PK 205+14.1), Abell 37 (PK 326+42.1), the Retina Nebula (PK 319+15.1), the White-Eyed Pea (PK 025+40.1), and the Little Ghost (PK 002+05.1). For more ideas and even fainter planetaries, refer to Don Goldman's superb images throughout this story.

Challenge yourself

Of course, you can choose to observe only the brightest examples from CGPN (2000), but where's the fun in that? I'm guessing you read about this catalog and are studying the images because you really want to dig deeply into it. So dig! Print out the PDF we posted on Astronomy.com and use it as a checklist for future observing sessions. I'm betting it won't be long before you develop a list of your own favorites from Luboš Perek and Luboš Kohoutek's famous planetary nebula catalog.



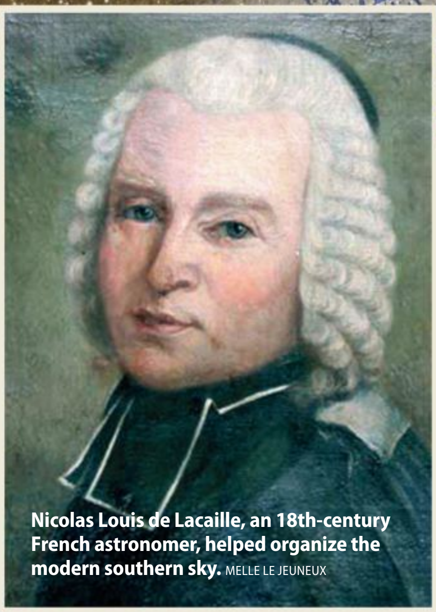
PK 111+11.1 has the common moniker Dengel-Hartl 5. Astronomers found this large nebula while searching Palomar Observatory Sky Survey plates in 1979. De-Ht 5 lies about 1,500 light-years away in the northern constellation Cepheus the King.

FIND ALL 1,510 OBJECTS IN THE 2000 VERSION OF KOHOUTEK'S *CATALOGUE OF GALACTIC PLANETARY NEBULAE* ONLINE AT **www.Astronomy.com/toc.**

Bringing order to the southern skies

Nicolas de Lacaille was a renowned astronomer in his day, but his most enduring influence lives on in constellations like Carina, Fornax, and Telescopium.

by Brian Jones



Nicolas Louis de Lacaille, an 18th-century French astronomer, helped organize the modern southern sky. MELLE LE JEUNEUX

On the morning of November 21, 1750, French astronomer Nicolas de Lacaille sailed out of L'Orient harbor in northwestern France aboard *Le Glorieux* bound for Cape Town in the Cape Colony (in present-day South Africa). One of the primary inspirations behind his voyage was a desire to map the stars south of the equator, a region of sky the second-century Greek astronomer Ptolemy had barely touched during the compilation of his *Almagest* and which had seen little study since. Navigation was increasing in the Southern Hemisphere, so it was becoming more important to know the exact positions of southern stars.

Among the few attempts to record the southern sky prior to Lacaille's visit to Cape Town was an effort by the English astronomer Edmond Halley, who visited the South Atlantic island of St. Helena in 1677. During his stay there, Halley charted the positions of nearly 350 stars, which appeared in his *Catalogus Stellarum Australium* in 1679. In addition to his main work cataloging the stars, Halley devised a new constellation named Robur Carolinum (Charles' Oak) to commemorate the tree where King Charles II hid following a military defeat. Like much of the southern sky, this constellation would not escape Lacaille's scrutiny unscathed.

Lacaille's early life

Nicolas Louis de la Caille (Nicolas de Lacaille, as he signed his name) was born around March 15, 1713, in the village of Rumigny in the Ardennes, France, although the exact date is uncertain. He was one of Charles-Louis and Barbe Rebuy's 10 children, and one of the few to survive to adulthood — his three brothers and three of his sisters all died young.

Lacaille was an avid reader in his youth, his interests including subjects such as antiquities, history, mythology, and Latin. During his early years, there was no real indication where his life would take him, but he eventually moved toward theology and the priesthood. Indeed, he was often referred to as Abbé Lacaille, despite only ever receiving minor orders and never becoming fully ordained. He eventually became a deacon to the chapel of Collège Mazarin, of the historic University of Paris.

The Collège Mazarin, part of the University of Paris, played an important role in Lacaille's life. He studied there and served as deacon of its chapel before eventually returning as a professor. ISRAEL SILVESTRE

Three years of studying theology coincided with a growing interest in astronomy and admiration for such from his contemporaries. Lacaille's studies led to his graduation as a Master of Arts and a Bachelor of Theology, although his growing knowledge of astronomy proved to be the true turning point in his life. His outstanding reputation and capabilities resulted in a recommendation to Jacques Cassini at the Paris Observatory, where he took up lodging and began astronomical observation and geodetic surveys, working alongside Cassini and Giovanni Domenico Maraldi.

Brian Jones *has written 15 books on astronomy, co-authored many more, and written articles for a large number of both general interest and astronomy-related magazines and journals.*

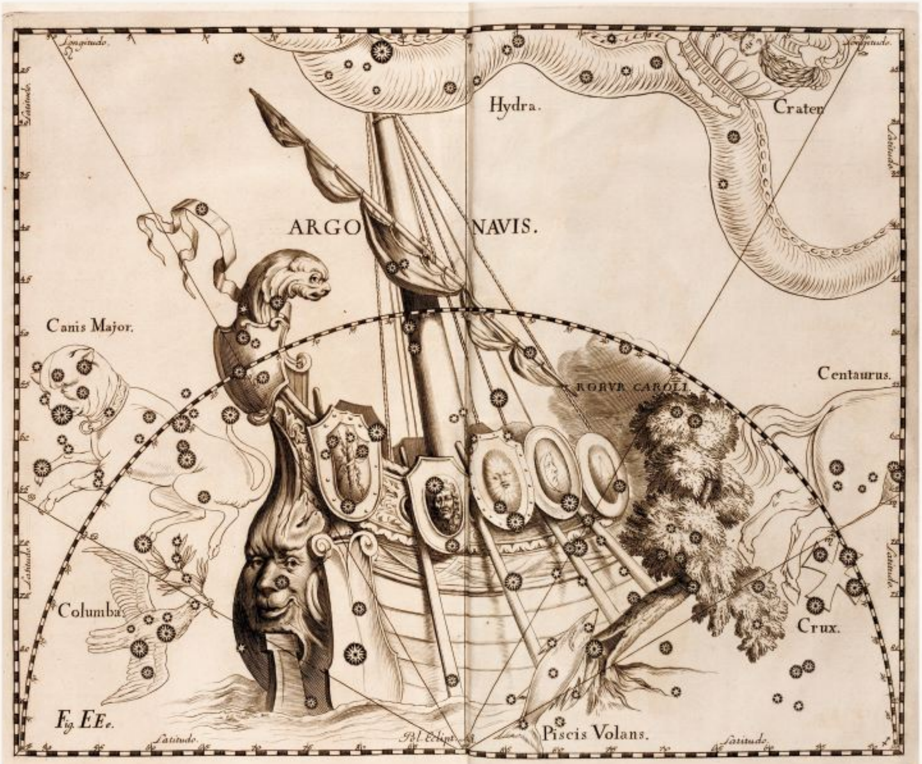
ASTRONOMY: KELLIE JAEGER

The skies take over

Lacaille's efforts at the observatory did not go unnoticed, and he eventually received admission to France's prestigious Royal Academy of Sciences. He accepted a professorship at Collège Mazarin around 1740, residing in a specially designed observatory where he acquired several fine astronomical instruments. In addition to publishing several books on astronomy and related subjects, he observed the transit of Mercury in 1743, measured the positions of comets, and cataloged planetary conjunctions, eclipses, occultations, and stars.

In 1750, Lacaille decided that the observatory had become too small for him, so he had a new one built at the southwestern corner of Collège Mazarin. This was larger and more suited to housing the impressive array of necessary instruments Lacaille had amassed. Soon after, though, his thoughts turned toward the Southern Hemisphere and to the continuation and completion of his ongoing work cataloging the stars.

Much of his effort during the preceding decade related to the positions of stars, reflecting his concern over the accuracy of astronomical observations. Thus, later that year, Lacaille approached the Royal Academy for approval to make a journey south. He wrote, "Having finished at Paris all the exact star observations I could make, I could not hope to realize my work in a more advantageous place than at the Cape of Good Hope, the most southerly inhabited place."



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The constellation Argo Navis, depicted here in Johannes Hevelius' 1690 work, *Uranographia*, proved too large and unwieldy for Lacaille, who broke it up into Carina the Keel, Puppis the Stern, and Vela the Sails.

To the south

The officials agreed to the expedition, and Lacaille left Paris on October 20, 1750, embarking on *Le Glorieux* about four weeks later. The voyage required stopping at Rio de Janeiro, where the ship's captain, Jean-Baptiste Nicolas Denis D'Après de Mannevillette, ordered maintenance and repairs. The visit took around a month before they set sail once more, eventually sighting the African coast at the end of March and reaching port April 19, 1751.

The Eta Carinae Nebula (NGC 3372), seen here in an infrared photo from the European Southern Observatory's Very Large Telescope, was one of 42 deep-sky objects first discovered by Lacaille during his time in Cape Town. ESO/T. PREIBISCH

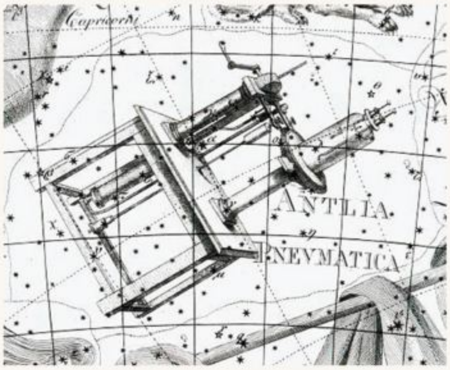
During the voyage, astronomy was never far from Lacaille's mind; he studied the December 13, 1750, lunar eclipse and made numerous observations during the stay at Rio de Janeiro.

Upon his arrival in Africa, Lacaille presented himself to Rijk Tulbagh, the governor of the Cape Colony, and received a warm welcome. Jan Lourens Bestbier, one of the leading citizens of the town, invited Lacaille to stay at his house while Tulbagh undertook to provide him with an observatory equipped for all his astronomical needs (including solid housings for his many instruments). Construction took only six weeks during May and June, after which Lacaille's observing program got under way.

Studying the southern skies

During his stay at the Cape, Lacaille took on a range of observing tasks. His work included measuring parallaxes of the Moon, Venus, and Mars, determining the exact altitude of the South Celestial Pole, observing the satellites of Jupiter, and recording the disappearances and reappearances of stars as the Moon passed in front of them. In addition, he carried out measurements to help verify the precise geographical location of the Cape of Good Hope.

Lacaille's main aim, however, was to determine the positions of the brightest southern stars; his original idea was to observe and catalog stars as faint as 3rd magnitude. He realized, however, that the available star catalogs of the time, including the one Halley compiled, included few stars below this brightness. Lacaille decided therefore to extend his searches to include all the observable naked-eye stars. As he later wrote, "I must … not content myself with observing only the stars brighter than the sixth magnitude, but observe also those which could be done easily no matter of what magnitude." With detailed study over the course of a year, and having undertaken to observe everything he could "see distinctly," Lacaille ultimately plotted the locations of more than 9,800 stars in the southern sky.



Antlia the Air Pump is one of the constellations Lacaille devised during his time in Cape Town. Like many of his new stellar groupings, it honors a technical device instead of a mythological figure or animal. JOHAN BODE/SHADOWXFOX

Lacaille eventually compiled a planisphere (a spherical chart) of the southern sky, published posthumously in his 1763 catalog, *Coelum Australe Stelliferum*, making "a catalogue of 1,930 stars chosen from the 9,800 which I had observed." This included "the southern constellations of the ancient Greek and Latin astronomers, and those added by the first Portuguese navigators." Conscious of the fact that large gaps remained in the charts he compiled, however, Lacaille proposed to fill them by introducing new constellations as well as by rearranging some existing star patterns.

Constellation consolation

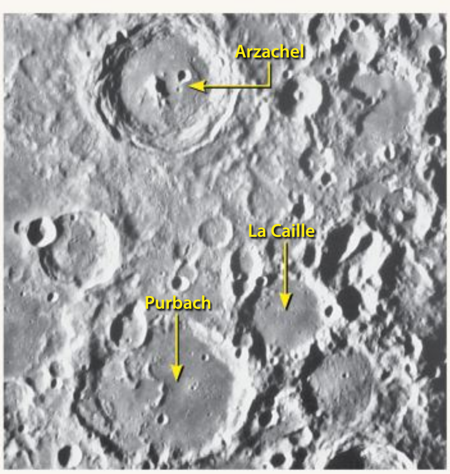
Representing the ship in which Jason and the Argonauts journeyed to Colchis in their quest for the Golden Fleece (and included in the list of 48 constellations cataloged by Ptolemy), Argo Navis was a large and somewhat unwieldy constellation, described by Lacaille as being "composed

of more than 160 easily visible stars." Lacaille dismantled the celestial ship, splitting it into the three separate constellations Carina the Keel, Puppis the Stern, and Vela the Sails, all of which have made their way onto modern star charts.

The sprawling Argo Navis wasn't the only star group to fall prey to Lacaille's restructuring. Recall that Halley had devised the tiny constellation Robur Carolinum from several bright stars in Argo Navis. Lacaille dismissed Halley's constellation during the reorganization of Argo Navis and reallocated the stars to the new group Carina.

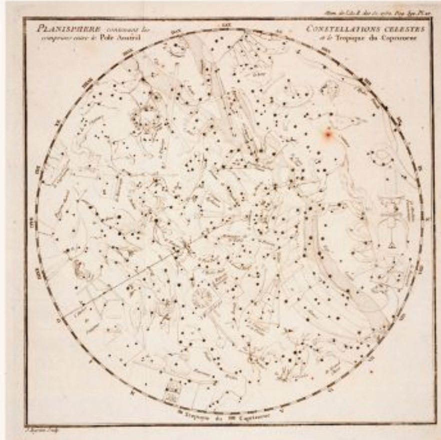
Lacaille's maps also included 14 new constellations of his devising, which modern charts also list. The list, which Lacaille described as representing "the principal figures of the arts," contains no creatures, mythological or otherwise. The new constellations were: Antlia the Air Pump, Caelum the Chisel, Circinus the Compasses, Fornax the Furnace, Horologium the Clock, Mensa the Table Mountain, Microscopium the Microscope, Norma the Square, Octans the Octant, Pictor the Painter, Pyxis the Compass, Reticulum the Reticle, Sculptor the Sculptor, and Telescopium the Telescope.

The names of some of these constellations offer easy clues as to the objects they depict, though some are a little more obscure. Lacaille introduced the tiny constellation Reticulum — located on the borders of Dorado the Goldfish, Horologium, and Hydrus the Little Water Snake — to pay tribute to the small reticle in his telescope, which helped him accurately catalog the southern stars. Caelum, in Lacaille's own words, represented "the burin of the engraver," and Octans depicted "the



CONSOLIDATED LUNAR ATLAS/UA/LPL

La Caille Crater lies in the Moon's south-central highlands. The French astronomer also has an asteroid named for him and several memorials in his honor, but his resting place is unknown and only one likeness of him survives.



Lacaille drew the first complete map of the southern stars, which was published in 1756. The spherical chart marked 14 new constellations and the division of Argo Navis into three new groupings.
LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, & TECHNOLOGY

reflecting octant of John Hadley, the principal instrument of navigators for observing the height of the pole."

In addition to his work on star positions, Lacaille discovered 42 deep-sky objects, including the Eta Carinae Nebula (NGC 3372), described by Lacaille as "many faint scattered stars in [a] circle 15–20 minutes [in] diameter filled with nebulosity." Also in the list are the Jewel Box Cluster (NGC 4755) in Crux the Cross and the magnificent globular cluster 47 Tucanae (NGC 104), which Lacaille said was "like the nucleus of a fairly bright comet."

Long return home

Seasonal bad weather, which prevented shipping to Europe from the Cape, extended Lacaille's stay by more than six months. He eventually left March 8, 1753, aboard the French ship *Le Puisieux*. His return journey took just over a year and included stops at the island nations of Île de France (now known as Mauritius) and Île de Bourbon (now know as Réunion), both off Madagascar's eastern coast. Among his work at Île de France, where he stayed for around nine months, was a series of measurements of meridian altitudes of the Sun, which helped him determine the precise latitude of the island. He eventually departed Île de Bourbon after six weeks there, on February 27, 1754, aboard *Achille*, which took him on the final leg of his homeward journey. He arrived at Paris on June 28, 1754, at which point he recorded:

Lacaille observed and studied eclipses, the Venus transit of 1761, and other astronomical events, but his work studying and organizing the southern skies may be his greatest contribution to science.
ROOSEVELT BESSONI

"Slept in Paris, where I had arrived at 4 P.M. Thus my voyage had taken three years, eight months, and one week."

Following his homecoming, Lacaille returned to his observatory at Collège Mazarin and again immersed himself in a busy work schedule, including the observation of 600 stars in the zodiac and the transit of Venus in 1761. He also worked on his memoirs, detailing his work at the Cape, and published his *Astronomiae Fundamenta* in 1757.

Indeed, Lacaille remained active almost until his death in 1762. Since first turning his attention to astronomy, he had undergone a rigorous program of research activity and writing. This seems to have finally caught up with him: Lacaille's death March 21, at the age of 49, was perhaps a result of the ordeals he had undergone during his efforts expanding our understanding of the universe.

Lacaille's observations were systematic and thorough, and he was arguably the first true pioneer of southern astronomy. His portrait, which hangs at the Paris Observatory, is the only real likeness we have of him. Numerous memorials stand in his honor, including a plaque near the site of his observatory at the Cape and other memorials at Rumigny and Curepipe, a town in the highlands of Mauritius. The 42-mile-diameter (68 kilometers) lunar crater La Caille is named in his honor, as is asteroid 9135 Lacaille, discovered in 1960. His final resting place, however, is unknown.

Yet by far the most glorious testimony to his achievements is the constellations he devised that continue to shine down from the southern skies, thereby ensuring that his pioneering spirit lives on.

What are we learning

Six missions to the Moon have yielded a treasure-trove of samples, providing insight into its origin, mineralogy, and evolution. **by Meenakshi Wadhwa**

Astronauts first set foot on the Moon on July 20, 1969, and there is now an entire generation of young adults who were born well after this seminal event in human history. Likely, many of them are not aware that the Apollo astronauts brought many hundreds of Moon rocks to Earth between 1969 and 1972. Now, more than 40 years later, where are these Moon rocks, and how much is left of them? What have we learned from them? And perhaps most importantly, is there anything more we can learn from them?

Rocky statistics

During the six manned missions to the lunar surface (Apollos 11, 12, 14, 15, 16, and 17), 12 astronauts explored six sites on the Moon's nearside and brought back 2,196 samples of rocks, soils, and cores with an original mass of about 839.9 pounds (381 kilograms). Of this mass, NASA distributed about 32 pounds (14.5kg) of carefully chosen samples to the science community. Researchers have analyzed approximately half this mass, and, with few exceptions, every one of those Apollo samples has been part of a detailed study.

Another 30 pounds (13.6kg) of Moon rocks are on long-term loan to various institutions around the world, mostly for exhibition purposes. Most of the Apollo samples, however, reside in safekeeping at the Lunar Sample Laboratory at Johnson Space Center in Houston. There, a dedicated team whose mandate is to protect, preserve, and distribute samples for future studies curates them.

Scientists continue to learn much from what the astronauts brought back. The fundamental insights gained from the study of the samples include ideas about how and when the Moon formed, how planetary orbits have evolved through time, and where and why water and other volatiles may be present on the Moon.

These new insights are literally changing our views of not only our lone natural satellite but also of Earth and our solar system. In fact, we are literally seeing a "new Moon" through the studies of these old samples that have now been with us for more than four decades.

The Moon's origin and age

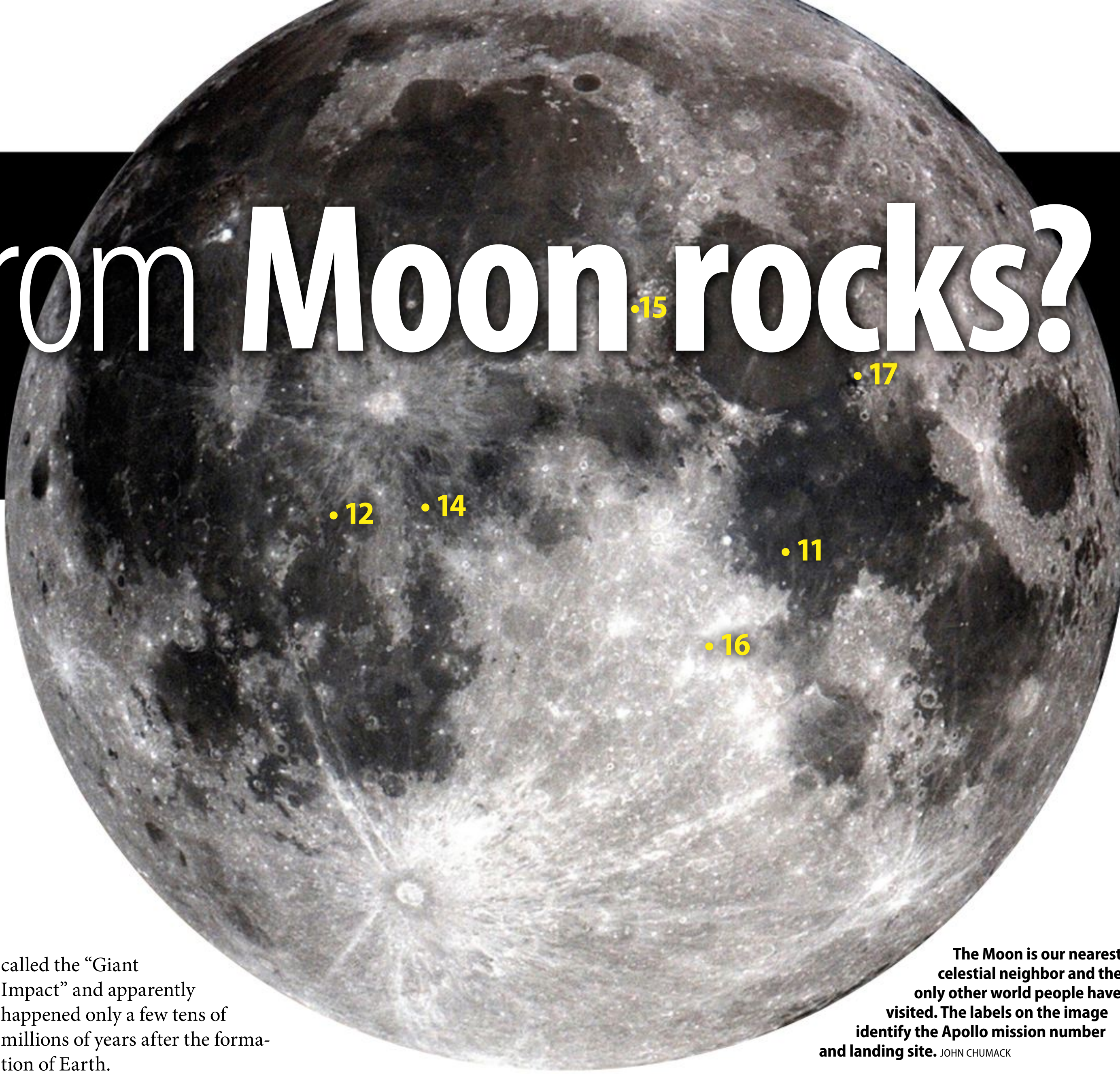
Studies of the lunar samples have told us that compared to Earth, the Moon has few volatile and siderophile (those that have an affinity for iron) elements but high quantities of refractory elements (those that remain stable at high temperatures). Yet isotope abundances of elements like oxygen indicate that Earth and the Moon have an ancestral relationship.

Based on such studies, the current best hypothesis is that the Moon formed when a Mars-sized planetary body slammed into the newborn Earth close to 4.5 billion years ago. This catastrophic event is popularly

Processing of Moon rocks occurs in the Lunar Sample Laboratory at Johnson Space Center in Houston. The laboratory became operational in 1979, 10 years after astronauts returned the first lunar samples. The facility stores more than 90 percent of the samples returned by the Apollo missions. MEENAKSHI WADHWA

Astronauts collected this basaltic sample from the Taurus-Littrow Valley during the Apollo 17 mission. Researchers have learned about the complex history of volcanism on the Moon from studying such rocks. NASA

from **Moon rocks?**



The Moon is our nearest celestial neighbor and the only other world people have visited. The labels on the image identify the Apollo mission number and landing site. JOHN CHUMACK

called the "Giant Impact" and apparently happened only a few tens of millions of years after the formation of Earth.

Recent advances in computing capabilities allow us to model this giant impact process. We now can explain many of the previously puzzling chemical features of the rocks the Apollo missions brought back from the Moon.

The chronology of lunar samples (based on dating methods that use various radioactive isotopes) can tell us about the detailed time sequence as well as processes involved in the Moon's formation and evolution. Soon after the Apollo 11 astronauts returned the first Moon rocks, scientists suggested that the Moon had an exceedingly hot beginning. Most of its crust likely formed from the solidification of a global

Meenakshi Wadhwa *is director of the Center for Meteorite Studies and a professor in the School of Earth and Space Exploration at Arizona State University in Tempe.*

MEENAKSHI WADHWA

The author felt right at home in the Lunar Sample Laboratory. All sample handling is done inside glove boxes, such as the one shown here, that contain an atmosphere of clean, dry nitrogen.

This Apollo 16 impact-melt breccia contains a variety of light-colored clasts (fragments of preexisting minerals or rock fragments). Some even enclose others, suggesting multiple generations of impacts and breccia formation on the Moon. Determining the ages of such impact melts can tell scientists something about the bombardment history of the Moon and Earth during the earliest stages of our solar system. NASA

Apollo 17 astronaut Harrison Schmitt — who was also a geologist — collects samples during his time on the Moon in December 1972. NASA

ROCK COLLECTING FOR NASA

With each subsequent Moon landing, Apollo astronauts collected more lunar samples than during the previous mission.

Mission	Site	Amount
Apollo 11	Sea of Tranquillity	47.8 pounds (21.7kg)
Apollo 12	Ocean of Storms	75.8 pounds (34.4kg)
Apollo 14	Fra Mauro	94.6 pounds (42.9kg)
Apollo 15	Hadley-Apennine	169.3 pounds (76.8kg)
Apollo 16	Descartes Highlands	208.8 pounds (94.7kg)
Apollo 17	Taurus-Littrow	243.6 pounds (110.5kg)

This sample from Apollo 15 contains green glass beads (inset). The largest are about 150 micrometers in diameter. The beads formed as a result of volcanism on the Moon. Recent measurements of the amount of water in such beads have shown that the Moon may not be as dry as scientists had previously thought. NASA

ocean of molten magma (lava) that was perhaps hundreds of miles deep.

In this scenario, the oldest rocks exposed on the Moon's surface should be those enriched in an aluminum-rich silicate mineral called plagioclase. Such material probably floated to the top of this solidifying magma ocean.

However, careful measurements of the ages of these Moon rocks give a range from close to the formation age of the solar system (about 4.5 billion years ago) to almost 200 million years later. This wide span in the ages of these plagioclase-rich rocks suggests that the Moon's crust likely formed by a process more complicated than the simple solidification of a magma ocean.

This Apollo 16 sample is anorthositic breccia. In 2011, a team of scientists determined a lunar age of 4.360 billion ±3 million years from this rock. The result suggests that the Moon is younger than researchers previously thought, or that the idea of such rocks forming as an early flotation crust from a lunar magma ocean may not hold. NASA

The lunar cataclysm hypothesis

Moon rocks also have helped us learn about the impact history and the orbital dynamics of planets, asteroids, and comets. Based on the ages of rocks heated and melted by large impacts, the idea of the lunar cataclysm (also called the Late Heavy Bombardment) was born, which also has implications for the quantity of impacts and the origin of life on Earth.

According to this hypothesis, sometime between 3.8 and 4.1 billion years ago, there was a huge increase in the number of asteroids and comets hitting the Moon. In fact, a recent study of Apollo samples searching for surviving impactor fragments found that most of the material hitting the Moon during this period was from asteroids.

If the lunar cataclysm hypothesis is correct, then this means that huge impacts also pummeled Earth, which may have delayed the beginnings of life on our planet. Dynamical simulation models show that the lunar cataclysm itself was likely the outcome of the migration of the gas giant planets early in the history of our solar system.

Gary Lofgren shows off a display case containing a sample from the Apollo 16 lunar mission. Lofgren has been the laboratory's Lunar Sample Curator since 1997 and just retired last year. MEENAKSHI WADHWA

That movement deflected some asteroids into the inner solar system. Researchers call this the Nice Model after the location of the laboratory (in Nice, France) where it originated in the 1990s.

Water on the Moon

For decades following the return of the Apollo samples, researchers thought the Moon's interior was essentially devoid of any water (less than one part in a billion).

The Core Sample Vacuum Container (CSVC) holds an entire drive tube section. Apollo 16 and Apollo 17 astronauts collected one each. After the samples arrived at Johnson Space Center, the curators placed both CSVCs in an additional vacuum container with a much better seal. Both containers remain sealed in the center's Curation Storage Vault. They will remain there in pristine condition for future studies. NASA

The Core Storage Area in the Pristine Lunar Sample Vault holds several of the most important lunar samples the astronauts returned. MEENAKSHI WADHWA

Recent advances in analytical instruments, however, have helped scientists find evidence of water and other volatile elements (like sulfur, fluorine, and chlorine) locked inside lunar rocks and minerals, indicating that the Moon is not as bone-dry as originally believed.

Although still only a fraction of the water that is in Earth's interior, the amount estimated inside the Moon — from a few to tens of parts per million — is substantial enough to require a re-evaluation of our ideas about how water came to the inner rocky planets. The latest findings highlight the fact that we can gain important new insights by applying modern, state-of-the-art techniques to samples that astronauts brought back from the Moon decades ago.

MEENAKSHI WADHWA

Researchers handle Moon rocks inside nitrogen-vented glove boxes in the Lunar Sample Laboratory.

The gift that keeps giving

The wonderful thing about having most of the Apollo Moon samples preserved in pristine condition at the Lunar Sample Laboratory is that they will be available for all kinds of future studies, many that we cannot even predict at present.

One of the more intriguing findings from recent spacecraft data (such as from the Moon Mineralogy Mapper instrument on Chandrayaan-1 and the LCROSS experiment on the Lunar Reconnaissance Orbiter) is the possible presence of water or hydroxyl (OH^-) in polar and nonpolar regions of the Moon.

If we can confirm the widespread presence of these compounds on the Moon's surface, it would be an important factor in determining the feasibility of future human exploration and long-term habitation of the Moon. In fact, there already may be samples in our possession that could help confirm or refute this idea.

Astronauts returned samples of lunar soil and two drive tube (a method of obtaining a soil sample as deep as 27.5 inches [70 centimeters]) sections taken during Apollo 16 and Apollo 17 in special vacuum-tight, sealed containers. Both drive tube sections and one soil sample remain sealed.

It is likely that state-of-the-art instrumentation now available would detect any water or hydroxyl in them. In fact, a consortium of researchers is in the process of carefully planning additional analyses of one of these sealed samples to answer some of the most pressing questions arising from recent spacecraft observations.

Still a lot to learn

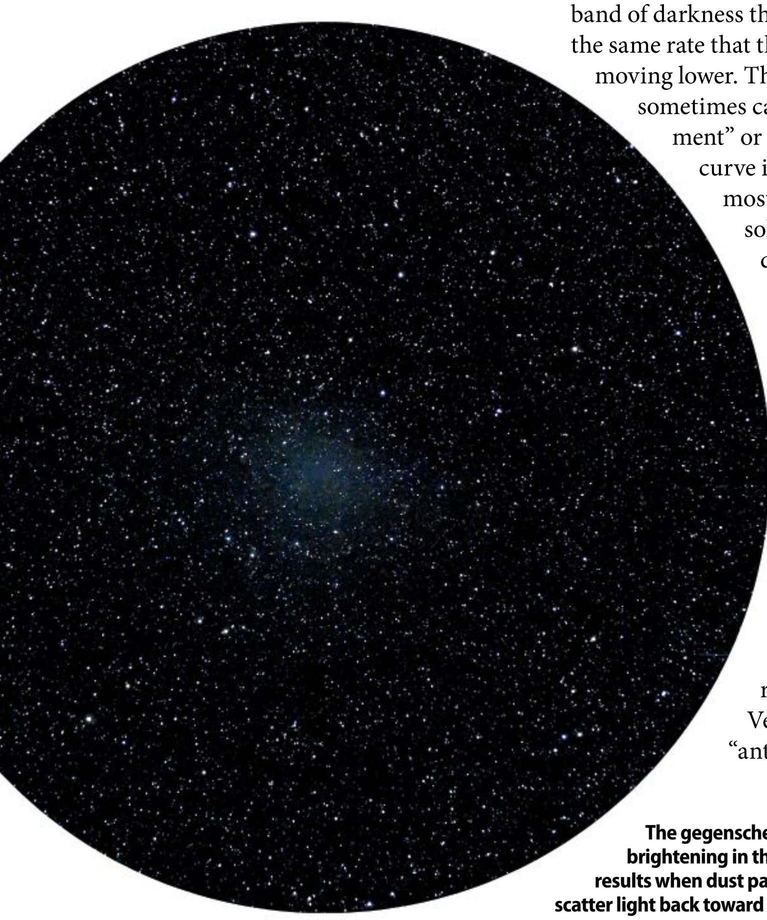
The Apollo samples returned more than four decades ago continue to provide a basis by which we can analyze the latest spacecraft data from the Moon. Through careful management, NASA's Johnson Space Center makes them available for today's scientists and future generations to help answer some of the most fundamental questions about our solar system.

We must remember, however, that these samples represent only a tiny fraction of the lunar nearside. Many other mysteries remain. Hopefully, the analysis of more and diverse samples returned by future missions to other areas of the Moon will unravel them.

Discover our solar system's **hidden wonders**

Set up your telescope and target martian clouds, Saturn's inner ring, a little-seen satellite of Jupiter, and more. **by Michael E. Bakich**

Because I hear from a large number of observers and imagers, I have a good idea which sky objects are popular and which ones are not. Unfortunately, "popular" often means the objects we default to during observing sessions, even if we realize there's a lot more out there to see. I suggest instead that you aim your telescopes away from the "tried and true" and toward a few seldom-viewed celestial targets you'll find right here in our solar system.



The gegenschein is the ever-so-slight brightening in the center of this image. It results when dust particles orbiting the Sun scatter light back toward Earth. JERRY LODRIGUSS

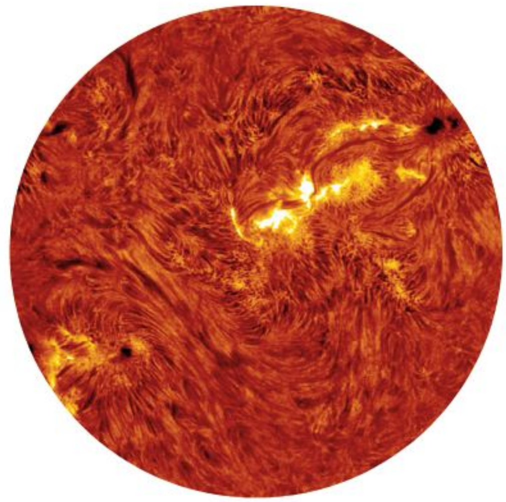
Planetary shadow

Let's start with a nearby sight you won't need optical aid for. Thousands of years ago, humans figured out that Earth's shadow blocks out the Moon during a lunar eclipse. But did you know you can see our planet's shadow on just about any clear evening? Head outside 15 minutes after sunset and look in the opposite direction from where the Sun disappeared — that is, across from the part of the sky that's still the brightest.

There you'll see a deep-blue, curved band of darkness that will climb higher at the same rate that the (now invisible) Sun is moving lower. That's Earth's shadow, sometimes called the "dark segment" or the "eclipsed sky." The curve is highest (and therefore most noticeable) at the antisolar point, which lies directly across from the Sun at your site.

You also can observe Earth's shadow in the morning sky before sunrise. Start looking for it in the west about 30 minutes prior to the rising of our daytime star.

If you see the dark segment, look directly above it for a brighter region called the Belt of Venus, also known as the "anti-twilight arch." This



Solar flares are easy to observe or image through a Hydrogen-alpha filter. These flares (the bright-white areas) occurred September 23, 2012, at 18h31m UT. JIM LAFFERTY

pink swath of light separates Earth's shadow from the sky above it.

The belt is the part of our atmosphere getting its illumination from the Sun at its lowest point. Because our star's light is passing through the maximum thickness of air, its blue light scatters out and the atmosphere it colors appears red.

By the way, the name "Belt of Venus" has nothing to do with the planet, which you will never see opposite the Sun. Rather, it refers to a magic girdle that Venus — the Roman goddess of love — wore to enhance her already remarkable attributes.

Ghostly glow

Our second target requires a much darker sky. And although it's unrelated to Earth's shadow, it does have one thing in common with it: We view both at the antisolar point. The gegenschein, also known as the counterglow, is sunlight backscattered by tiny particles of interplanetary dust, which abound in the plane of our solar system.

Spotting this faint patch is a tough observation. It appears only marginally

This image of the Full Moon setting over Elba, Italy, shows our lone natural satellite within the pinkish-orange Belt of Venus and just above the dark shadow cast by our planet. The imager, who took the picture remotely August 14, 2011, at 5:28 A.M. local time, looks on. STEFANO DE ROSA

brighter than the background sky. You won't see it if there's any light pollution. You won't see it if the Moon is out. You won't see it during the summer or winter because the Milky Way then lies at the antisolar point, and that stellar band is brighter than the counterglow. Finally, you won't see it more than about an hour on either side of the middle of the night, which may be 1 A.M. if daylight saving time is in effect. You have to catch the gegenschein when it stands highest in the sky.

Boom goes the Sun!

Let's continue our journey by checking out our Sun. Solar flares occur when its atmosphere suddenly releases built-up magnetic energy. These events emit radiation storms and are gigantic explosions.

To see a flare requires a telescope (any size) and a Hydrogen-alpha solar filter that you can attach securely to it. Point that setup at the Sun, use a magnification of 100x or more, and look for bright-white areas that you can see change in shape, normally in just a few minutes.

Astronomers classify flares by how much area on the Sun they cover at the time of maximum brightness. They range from subflares (smaller than 2 square degrees) to Importance 4 flares, which cover more than 24.8 square degrees. On the Sun, 1 square degree equals roughly 57 million square miles (150 million square kilometers). The current peak in solar activity has resulted in amateur astronomers viewing and imaging many large flares.

Invisible Moon

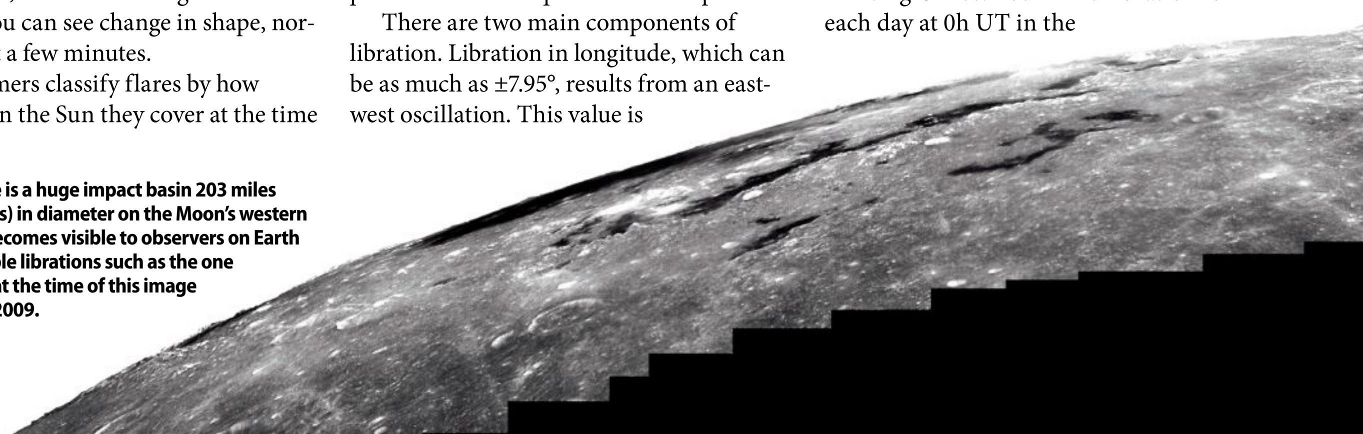
Now we'll head back into the night sky. As we turn our attention to our lone natural satellite, it's time for a bit of vocabulary work. Because tides between Earth and the Moon have locked our nearest celestial neighbor in place, the same hemisphere always faces us.

But that doesn't mean we see only 50 percent of its surface. In fact, a complicated motion called libration lets us at times see a bit around the eastern and western edges and somewhat beyond the north and south poles. The bonus equals an extra 9 percent.

There are two main components of libration. Libration in longitude, which can be as much as ±7.95°, results from an east-west oscillation. This value is positive if you can see more of the Moon's eastern side. Negative means more of the western Moon is in view. Libration in latitude, which can be as much as ±6.85°, comes from a north-south oscillation. Positive means more of the Moon's northern terrain is visible; negative means the south is predominant.

Unfortunately, libration circumstances change constantly. If you want to observe the "hidden 9 percent," you'll need a reference. Some astronomical software, such as *TheSkyX* from Software Bisque, list libration values, and so do two annual publications. The first is the *Observer's Handbook*, published by the Royal Astronomical Society of Canada. In its "The Sky Month by Month" section, you'll find each month's greatest values of lunar libration in each direction. Target those dates.

For a day-to-day account, use *The Astronomical Almanac*, distributed in North America by the U.S. Government Printing Office. You'll find libration for each day at 0h UT in the



Mare Orientale is a huge impact basin 203 miles (327 kilometers) in diameter on the Moon's western limb. It only becomes visible to observers on Earth during favorable librations such as the one that occurred at the time of this image September 9, 2009.
DAMIAN PEACH

This image, taken January 8, 2012, shows several different cloud types above the surface of Mars. Three prominent orographic "domino clouds" (as the imager called them) float over the Tharsis volcanoes. Above them, a bright cloud lingers over Amazonis Planitia. To the right and just above center, wispy clouds fly over Alba Patera. DONALD PARKER

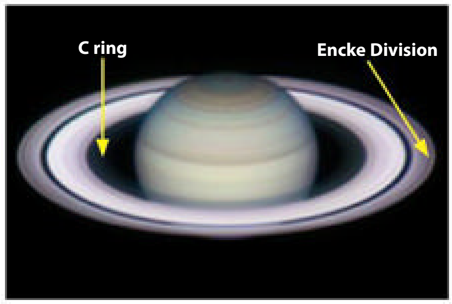
first table of "Section D Moon." Please note, however, that the publication doesn't label the numbers "libration." Rather, the first two columns on the right-hand pages give "The Earth's Selenographic" "Long." (column 1) and "Lat." (column 2). Those are the numbers that will tell you the amount of libration.

Cloudy with a chance of Mars

Now it's time to visit a planet. When the Red Planet stands high in the sky, look for martian clouds, of which several different types exist. All are temporary phenomena.

Seasonal clouds occur due to summer heating or winter cooling that cause sublimation and condensation, respectively. Discrete clouds usually remain with a specific

Jupiter's moon Himalia sometimes travels as far as 1° from the giant planet's glare. At such times, the magnitude 14.8 speck is visible through a 14-inch or larger telescope. NASA/JPL/UNIVERSITY OF ARIZONA



Both the Crepe ring (also called the C ring) and the Encke Division are visible in this image taken January 13, 2005, the night Saturn arrived at opposition. The C ring is the dark band closest to Saturn, and the Encke Division is the slight dark gap near the outer edges of the rings. DAMIAN PEACH

area, moving as the planet rotates. You'll find most discrete clouds in Mars' northern hemisphere during its spring and summer.

Astronomers call certain discrete clouds orographic clouds. Wind passing over the high peaks of mountains and volcanoes creates them. These water clouds lie at high altitudes. A blue or violet filter generally works best to observe them.

If you have access to an 8-inch or larger telescope, try to observe the Syrtis Blue Cloud of Mars. This is a famous discrete cloud associated with the Libya Basin as well as Syrtis Major.

Viewed without a filter, the cloud turns Syrtis Major bluish, so, if you want to confirm that it's there, insert a yellow eyepiece filter, which will turn the portion of Syrtis Major covered by the cloud green.

Move away from Mars' central meridian (the north-south dividing line), and you may see morning and evening clouds. These bright, isolated patches of surface fog show up best at sunrise (on the planet's western edge) or sunset.

Evening clouds are generally larger and more numerous, and they get even bigger as the martian night approaches. Your chances of seeing these clouds are better through a blue or violet filter.

Ring around the planet

Our next observation targets a true astronomical all-star: Saturn's rings. If you're using a 2-inch or larger scope at low power, you'll see the Cassini Division, a broad, dark gap between the A and B rings. At magnifications above 300x, look for the elusive Crepe ring (also called the C ring), which lies closest to the planet. I can see it through my 4-inch refractor, but only on nights where the seeing (atmospheric steadiness) is great. Through an 8-inch or larger instrument during a time when the rings are open — that is, when their tilt is near maximum — the Crepe ring is one of Saturn's finest features.

If the Crepe ring is visible, try for the Encke Division. This gap, which is much narrower, lies near the outer edge of the A ring about four-fifths of the way from the Cassini Division to this edge.

Through small telescopes, some observers see a feature often called the Encke Minimum, which is a decrease in brightness of the A ring. Telling this feature apart from the Encke Division is a matter of position. The Encke Minima (plural when visible on both sides of the ring) lie at the A ring's center. The true Encke Division is much nearer the outer edge.

Through my 4-inch telescope, I can view the Encke Minima when seeing permits, but I have to use magnifications upward of 300x. I cannot see the Encke Division through this scope.

Can you see this moon?

I'll end our interplanetary tour by inviting you to try a challenging observation. American astronomer Edward Emerson Barnard discovered Jupiter's fifth moon, Amalthea, in 1892. It was the last satellite discovered by putting eye to eyepiece. On December 3, 1904, American astronomer Charles Dillon Perrine discovered a sixth satellite, Himalia, albeit photographically. It ranks sixth in size and fifth in mass.

At its brightest, Himalia glows at a meager magnitude 14.8, or 0.7 magnitude fainter than Amalthea. It is, however, easier to see. That's because Himalia's greatest distance from Jupiter (nearly 1° from the giant planet at its farthest point) is more than 60 times that of Amalthea's, so it doesn't get lost in the planet's glow.

I have made confirmed observations through a 10-inch telescope, but those were tough sightings under a pristine sky. A 14-inch or larger instrument will give you a good chance of success.

The near sky beckons

While some observers claim that much of amateur astronomy's allure comes from observing 14th-magnitude planetary nebulae or clusters of galaxies billions of light-years away, there's a lot to be said for some sights much closer to home. I hope my tour has given you a helpful road map to a few great sights our solar system offers.

Michael E. Bakich *is an* Astronomy *senior editor and author of* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*

Vixen's GPD2 mount tested

This accessory features portability, superb craftsmanship, and high-quality tracking. **by Tony Hallas**

Vixen's GPD2 Equatorial Mount is the latest in a long line of Polaris mounts the company has produced. VIXEN OPTICS

If you've read any of my columns in *Astronomy*, you know that I do a lot of astroimaging and value high-quality equipment. And next to a telescope's optics, the most important piece of equipment is the mount.

I installed a permanent mount in my home observatory. It's large and routinely carries telescopes like my 14.5-inch Cassegrain reflector. But I also like to shoot with smaller wide-field telescopes and camera lenses, especially from ultra-dark sites like Alturas in California, which I wrote about in the April 2012 issue ("The Modoc Plateau beckons amateur astronomers").

For those times, I need a portable mount that's more than just a tracker, one with an accurate polar-alignment scope and a reasonable price tag. After I saw Vixen's GPD2 Equatorial Mount at the 2012 Northeast Astronomy Forum, I decided to buy one.

A long pedigree

Long ago, when I used to image from the summit of Mount Pinos in Ventura County, California, there were always individuals up there with portable Vixen Great Polaris mounts. Those of us with our massive Schaefer German equatorial mounts would quietly sneer at their lack of substance, and during times when the wind was blowing 25 mph (40 km/h) in the parking lot, only the Schaefer mount owners could still image. But when it was time to pack up on Sunday, the owners of the portable mounts picked them up with one hand, folded their tripods, and were gone in 10 minutes!

So, the Great Polaris mount has a long history. The early Polaris, the Super Polaris, and the Great Polaris have gone through many improvements that have culminated in the current GPD2 model, the sturdiest (and heaviest) of this line of mounts.

"Heavy" is relative — the mount weighs only 18.7 pounds (8.5 kilograms) and can hold up to 35 pounds (16kg). The mount disassembles easily because the declination (Dec.) half attaches to the right ascension (R.A.) component by only two bolts. Users also can remove the Dec. shaft. Doing so will allow splitting up the mount for air travel between two carry-on bags if need be — a handy feature.

This picture shows the GPD2 mount with the author's typical imaging setup. TONY HALLAS

The Dual Axis Motor Drive Set comes with a hand paddle. It lets you slew at three rates that are multiples of the stars' apparent motion: 1.5x, 2x, and 32x. TONY HALLAS

Features

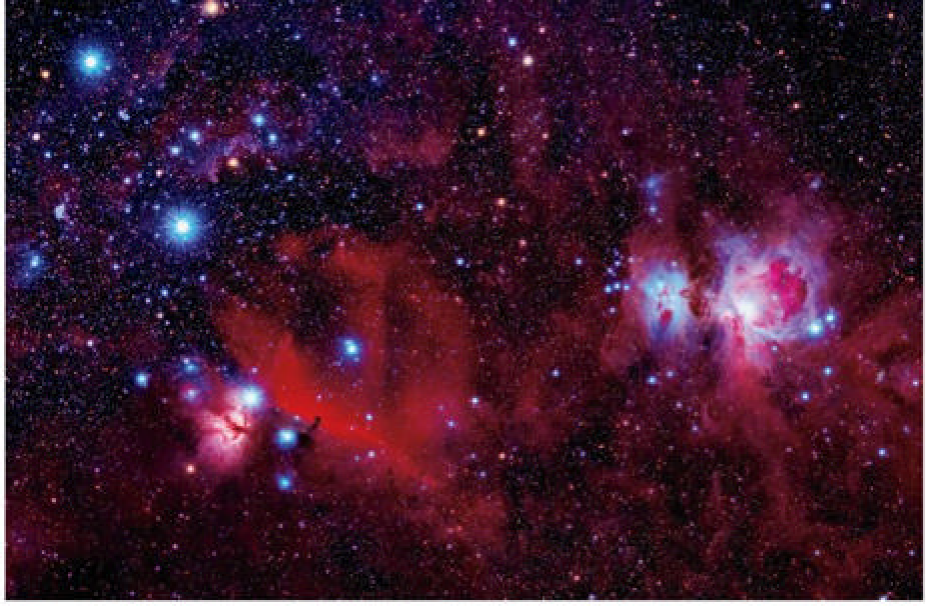
Along with the GPD2 mount, Vixen includes as an optional accessory the STARBOOK-S, a planetarium software-driven processor that will slew to objects in its internal database. This requires that you set up the mount like those in the Sphinx series (entering time, date, location, etc.). I didn't want to do that because my use was strictly wide-field imaging. I opted, therefore, for the standard hand paddle and the simple stepper-motor drives.

The hand paddle has three slewing speeds: 32x for rapid slewing to get you near your target, and 2x and 1.5x for guiding. I noted some hysteresis (hesitation) in the stepper-motors at 32x. The mount momentarily stopped tracking until the internal gears re-engaged. This didn't happen at the slower rates.

How well this little mount can track really impressed me. As Vixen advertises, technicians hand-inspect each mount to keep the accuracy of the worm-gear assembly within 0.002 millimeter to minimize periodic error. It shows. I took 3-minute unguided shots with a 200mm lens pointed south and had perfectly round stars.

The hand paddle has an input for Santa Barbara Instrument Group-style guiders. This is a huge plus. It means you can use any number of guiders and software that support this popular format. Just make sure when you do anything involving guiding that you have the speed set to 2x or 1.5x. I somehow always forgot to set the speed down from 32x, and the result was chaos and a lot of comments no one should hear.

The GPD2 mount features an internally illuminated polar-alignment scope. TONY HALLAS



The author used the GPD2 mount when he took seven 2-minute unguided exposures, which he combined into this image that shows the region around Orion's Belt. He used a Canon 6D with a Canon EF 200mm f/2L IS USM telephoto lens set at f/3.2 and ISO 1600. TONY HALLAS

The mount comes with setting circles that you can use to move from target to target. This feature, nice as it is, is primarily for old-school observers. I am comfortable with star-hopping because, like many imagers, I already have memorized the locations of the wide-field objects I want to shoot.

Vixen designed a lightweight dedicated tripod for the GPD2, which it calls the HAL 130 Aluminum Tripod ($249 from Vixen). Make sure you also order the Triangle Accessory Tray ($34.95 from Vixen) that bolts to the legs. Not only does this provide a handy place to store items in use, but it also stabilizes the legs considerably. And if you want the ultimate in stability, place a reasonable weight in the tray. I use a small bag of sand that weighs 10 pounds (4.5kg).

The GPD2 has an internally illuminated polar-alignment scope that lets you set the day and hour by turning the entire R.A. assembly. I fine-tuned this device by careful drift-aligning and then loosened the appropriate set screws and made sure Polaris (Alpha [α] Ursae Minoris) was where it was supposed to be for that particular time and date.

Now all the dials work as a "computer" to calculate where Polaris should be at any time and date. All I have to do is adjust the mount until Polaris is in the correct place.

I was a little disappointed that Vixen did not include the superior (in my opinion) alignment scope from the Sphinx mount series, which rotates without having to actually turn the R.A. This allows polar aligning with the mount loaded, whereas you have to turn everything attached to the mount upside down with the GPD2, which can be somewhat awkward.

Clever tech

For the technically minded, the mount uses 144-tooth brass wheel gears on both axes and steel worm gears. Turning the gears by hand reveals that the action is smooth, the mark of a carefully made mount.

For low-power viewing, you don't even need the motors, but for tracking and guiding, I suggest you get the Dual Axis Motor Drive DD-3 Set ($429 from Vixen), which includes two motors, a hand paddle, and a D-size battery pack that you load with eight batteries to make a 12-volt DC power source. Instead, I attach two alligator clips to the wire and use a small deep-cycle rechargeable battery as my power source because it provides power for a lot longer.

I want to mention one more thing about the DD-3 motor set. To attach the motors to the R.A. and Dec. worm gears, you have to remove the knobs that let you slew the mount manually. But then you can't move it manually because the motors lock both axes until you provide power.

To address this issue, Vixen has created a clever clutch assembly that disengages the motors, letting you physically slew the mount. When a large distance separates two sky objects, I prefer to release the mount clutches, move the scope to the general area, retighten the mount clutches, and fine-tune with the 32x electric slew.

Extras

The mount interfaces to equipment via two styles of plates. One is the small Universal Dovetail Tube Plate ($18.95 from Vixen), which works well for holding anything like a telescope tube. And to make the small plate even more versatile, you can drill out its center and recess a ¼-20 machine bolt to allow fastening a single item like a camera. The other is the SX Large Accessory Plate ($219) — a massive flat plate that can hold a large variety of items.

Vixen includes two counterweights with the GPD2, one that weighs 4.2 pounds (1.9kg) and a heavier one that tips the scales at 8.15 pounds (3.7kg). If you need more, you can purchase them as accessories. (An extra 4.2-pound counterweight costs $79, and the 8.1-pound version is $109.)

A great deal

In sum, I am more than pleased with the GPD2 mount. Its solid construction, high-quality workmanship, and careful assembly and testing represent real value for your money. This is one piece of astro-gear that should give you years of enjoyable service.

Tony Hallas *is a contributing editor of* Astronomy. *He writes the "Cosmic Imaging" column each month.*

PRODUCT INFORMATION

Vixen GPD2 Equatorial Mount
Motor drive: Optional with STARBOOK-S or Dual Axis Motor Drive DD-3 Set
Maximum loading weight: 35 pounds (16 kilograms)
Weight: 18.7 pounds (8.5kg)
Counterweights: 4.2 pounds (1.9kg) and 8.15 pounds (3.7kg)
Price: $999; $1,149 with HAL 130 Aluminum Tripod
Contact:
Vixen Optics
1023 Calle Sombra, Unit C
San Clemente, CA 92673
[t] 949.429.6363
[w] www.vixenoptics.com

SECRET**SKY**

BY STEPHEN JAMES O'MEARA

Rare rainbow phenomena

The rainbow that we think of as familiar can have some surprising variations.

In December 2012, Deborah Carter of Maun, Botswana, was visiting a friend in Cairns, Australia, when the "sky started to darken and the wind got up, and we knew we would have to quicken our step in order to escape the incoming rain. So we walked a little faster, and then I noticed a rainbow forming." Carter snapped a few photos of the sight with her iPhone and later asked me about their details. What especially fascinated her was the "difference in the color of the sky below and above the rainbow."

In contrast

What Carter had actually seen was a bright double rainbow. And one of the most notable characteristics of such a sight is that the sky between the primary and secondary arcs appears darker than regions surrounding it. Alexander of Aphrodisias first described this curiosity in A.D. 200 in his commentary on the fourth volume of Aristotle's *Meteorology*. Today, skywatchers continue to rediscover it whenever two rainbows appear at once.

Now popularly known as Alexander's Dark Band (after Alexander rather than a ragtime ensemble), this cheerless segment of the daytime sky's most colorful and uplifting display is largely a contrast phenomenon. In addition to the raindrops that form the two spectral rings, there are other raindrops that send light rays either toward the center of the primary bow or to the outside of the secondary bow. This leaves a region largely devoid of reflected light, which looks dark in contrast to the two light regions.

Rainbows are concentric arcs of multicolored light that appear in rain-washed skies and are centered directly opposite the Sun at a place known as the "antisolar point." The brightest displays associated with Alexander's Dark Band have primary bows 42° from the antisolar point and secondary bows that stretch 51° away from it. The highest bows occur at sunrise and sunset. The primary always has blue/violet light on the inside and red light on the outside, while the opposite is true for the secondary bow.

Radial streaks

Aside from the phenomenon Carter described, one of her images also caught my attention because it captured an uncommon occurrence — a "rainbow wheel" or "spoked bow" — one that I have yet to see myself. Let's look closely at this rare sight.

In her close-up shot of the primary bow, Carter recorded dark and light radial streaks like the spokes of a wheel descending from the primary toward the rainbow center.

"The darker spokes are produced by small clouds outside the rainbow and nearer the Sun that cast long shadows across the sky," explains Les Cowley, a retired physicist and an expert in atmospheric optics (www.atoptics.co.uk). "Their shadows are normally invisible, but when they block sunlight from reaching rainbow-forming raindrops, we see them as dark spokes. The spokes can be even more dramatic when seen in real life or on video, for they sometimes rotate around the rainbow, turning it into a wheel."

Paying attention to the sky, even in the daytime, can yield views of rare events like wheels spinning in the sky. While we are all familiar with regular, single rainbows, different weather and atmospheric conditions make the variants of this phenomenon fascinating to observe.

As always, let me know what you see and think at someara@interpac.net.

Deborah Carter snapped these rainbow shots with her iPhone. The left image shows a double rainbow with Alexander's Dark Band between the bows. The right photograph reveals a rare rainbow phenomenon: a rainbow wheel or spoked bow. DEBORAH CARTER

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Sarah Scoles**

Cold as space — Supernova hot

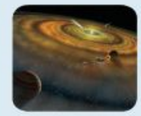
Spoiler alert

In 2020, the European Space Agency and the Johns Hopkins University Applied Physics Lab will try to change the path of a nonthreatening binary asteroid. If the mission succeeds, maybe Bruce Willis will finally return a few of the scientists' fan letters.

Regression therapy

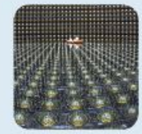
NASA agrees to buy Bigelow Aerospace's inflatable addition to the ISS. After installation, astronauts will test it against radiation, temperature, and impacts such as those caused by treating the $18 million module as a bounce-house.

Truth is out there



The discovery of six comets orbiting stars other than the Sun leads to the conclusion that dirty snowballs are common in other planetary systems. SETI researchers may do a targeted search for transmissions from alien doomsday cults.

Sustainability



Pulsing LEDs on Mariko Mori's sculpture "Tom Na H-iu II" change color when a neutrino hits the Super-Kamiokande detector at the University of Tokyo. Because why do it yourself when you can have the universe do it for you?

ASA/JPL-CALTECH/UCLA/MPS/DLR/ IDA (SPOILER ALERT); NASA/BIGELOW AEROSPACE (REGRESSION THERAPY); NASA/FUSE/LYNETTE COOK (TRUTH IS OUT THERE); KAMIOKANDE OBSERVATORY/ICRR/UNIVERSITY OF TOKYO (SUSTAINABILITY)

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

BY KARRI FERRON

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Observing Basics

Insights from a senior editor's "little corner of the universe"

Senior Editor Michael E. Bakich has logged tens of thousands of hours at the eyepiece and knows plenty about observing, from the equipment to use to the objects to target. His office at *Astronomy* is the place to go for questions on everything from the best globular clusters to the best eyepieces. And now Bakich is inviting you into his office, or, as he calls it, his "little corner of the universe," to explore the various questions you may encounter when starting your own observing adventure in his *Observing Basics* video series.

In each quarterly episode, Bakich takes a few minutes to tackle a topic based on frequent questions he receives from readers. For example, the first episode is all about "Buying binoculars," in which Bakich provides five tips to help you pick quality equipment. Another explains what the numbers on eyepieces signify and, in turn, what they mean for your observing experience. And one even shows you how to use a finder scope.

But Bakich covers more than just equipment. He even explores concepts important at the eyepiece, from understanding cosmic distances to dealing with dew. Beginners, be sure to check out all the videos in the "How To" section of **www.Astronomy.com/equipment**.

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OBSERVING TOOLS

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COSMIC**IMAGING**

BY TONY HALLAS

Understanding deconvolution

This complicated technique performs one simple task: It sharpens your images.

I first heard about deconvolution many years ago from a friend who told me about the image-processing software *CCD Sharp* from Santa Barbara Instrument Group. When you used the software, and if everything was just right, you watched in awe as your celestial image mysteriously sharpened.

The one drawback to this procedure was the background of your image: More often than not, it "curdled" and ended up looking like cottage cheese. In this article, I'll explain what deconvolution is, and in next month's column I'll show you how to actually use it.

In a perfect world, any celestial object we record would be as sharp as the telescope would allow. We know this almost never happens, so astroimagers often represent this with the equation RS = PS × BE, where *RS* represents the recorded signal, *PS* is the perfect signal (by which I mean a totally sharp star), and *BE* is the blurring effect caused by a combination of bad seeing (a measure of atmospheric steadiness) and bad optics.

So, an outside factor has convolved (rolled together) the perfect signal to create a blurred image. If we can estimate and model this factor, we can mathematically deconvolve the blurring and recover most of our sharp image.

Note that good signal-to-noise ratio is very important when attempting deconvolution. In fact, the better it is, the better deconvolution will work.

To initiate deconvolution, we need to estimate the amount of blur, or what imagers refer to as the point-spread function (PSF). They define this as the response of an imaging system to a point source of light (a star).

Our imaging system includes all elements that affect a point source. Examples are the seeing, the collimation (alignment of the optics), the cleanliness of the optics, internal thermal effects, focus, and more.

We can estimate the PSF by sampling unsaturated stars in our image. It's important to note that in this step we are only making an educated guess at the value of the PSF, or making a "blind deconvolution." Knowing this, trying different PSFs based on our original estimate can be beneficial to finding the optimum setting.

How do you know when you have gone too far? The most common unwanted artifact from deconvolution is the appearance of dark circles around your stars. The other artifact, as mentioned earlier, is the breakup of the background. This is closely related to how smooth the image is to begin with; hence I emphasize that you try to have the highest signal-to-noise ratio possible.

To address the curdling artifact, high-end software routines include a noise filter. That way, the user can adjust the amount of filtration in relation to the noise level of the image.

Deconvolution software is multi-iterative, meaning that the user specifies how many times the program processes the image. Besides all the other settings we will examine next month, finding how many applications of the deconvolution routine the image can sustain before artifacts appear is critical to the best outcome.

Needless to say, the math involved is complicated (if you are curious, look up deconvolution on the Internet). Fortunately on our end, all we need to know is how to use the various settings, and this we will investigate in July's column.

This luminance image of the Fireworks Galaxy (NGC 6946), which lies in the constellation Cepheus the King, appears a bit fuzzy. In addition, the stars all look bloated. ALL IMAGES: TONY HALLAS

After the author applied deconvolution to his image of NGC 6946, details in the galaxy appear sharper, stars are smaller, and even the background looks darker.

FROM OUR INBOX

The search for solar system twins

I have enjoyed my subscription to *Astronomy* magazine, which I read from cover to cover. I find each issue packed full of interesting and varied articles. One of my favorite topics that receives extensive coverage in your magazine is the search for extrasolar planets. It still amazes me that a bunch of hairless apes have figured out how to detect, and in some cases "see," planets orbiting stars light-years away.

I feel that these articles are missing one important piece of information, however. The majority of extrasolar systems detected so far contain planets with orbits that make them quite different from our solar system — such as Jupiter-sized worlds that lie closer to their stars than Mercury is to the Sun. Based on these observations, we are led to believe that our solar system is unique. The fact of the matter is we simply have not been looking long enough to find a solar system like ours.

The Kepler spacecraft has been in service four years, and that means that for a planet with roughly Earth's orbital period, only four occultations could have been recorded by now; that's not a lot of data to reliably detect a small planet. Consider also the orbits of our solar system's gas giants Jupiter and Saturn — it could take at most 11.9 and 29.5 years, respectively, for Kepler to observe similar worlds orbiting their star just once. To conclude that our planetary system is a rarity is premature; we simply haven't been looking long enough. **— Jim Thompson,** Ottawa, Ontario, Canada

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NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

Eyepiece line
Olivon USA, Roswell, Georgia
Olivon produces its 80° ED Wide Angle Eyepieces with focal lengths of 11mm, 15mm, 16mm, 20mm, and 30mm. The 11mm and 15mm units have 1¼" barrels while the other three sport 2" barrels. All five have full multicoatings.
Price: $74 to $190
[t] 770.640.9692
[w] www.olivonusa.com

Focuser
Orion Telescopes & Binoculars
Watsonville, California
Orion's 2" Low-Profile Dual-Speed Hybrid Reflector Focuser uses a special gear for more load capacity than a standard Crayford focuser. It has a dual-speed focuser with 11-to-1 reduction and works with 8- and 10-inch reflectors. The unit's racked-in height is 2.3 inches (58 millimeters), and it weighs 14 ounces (397 grams).
Price: $249.99
[t] 800.447.1001
[w] www.telescope.com

Wide-angle eyepiece
Meade Instruments, Irvine, California
The Meade Series 5000 Xtreme Wide Angle 20mm Eyepiece features blackened lens edges and internal surfaces as well as a parfocal design for little focus change between eyepieces of the series. It offers a 100° apparent field of view.
Price: $499
[t] 800.626.3233
[w] www.meade.com

1¼" eyepiece
Tele Vue Optics, Chester, New York
Tele Vue Optics' Delos EDL-08.0mm eyepiece has a 72° apparent field of view, a 9.9-millimeter field stop, and 20mm of eye relief. The unit weighs 16 ounces (455 grams), has a 1¼" barrel, and features an adjustable eyeguard system.
Price: $370
[t] 845.469.4551
[w] www.televue.com

Off-axis guider
Celestron,
Torrance, California
Celestron's Off-Axis Guider uses an adjustable, multicoated 12.5-millimeter prism that allows you to locate a guide star. It has a fixed-orientation helical focuser and includes all needed spacers and adapters for most imaging configurations.
Price: $249.95
[t] 310.328.9560
[w] www.celestron.com

Telescope alignment accessory
Celestron, Torrance, California
Celestron's StarSense Accessory lets you align your Celestron computerized telescope in three minutes or less without your having to locate or identify any stars. It also provides advanced mount modeling.
Price: $329.95
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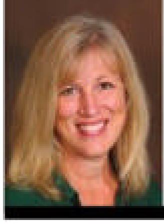
BY ERIKA RIX



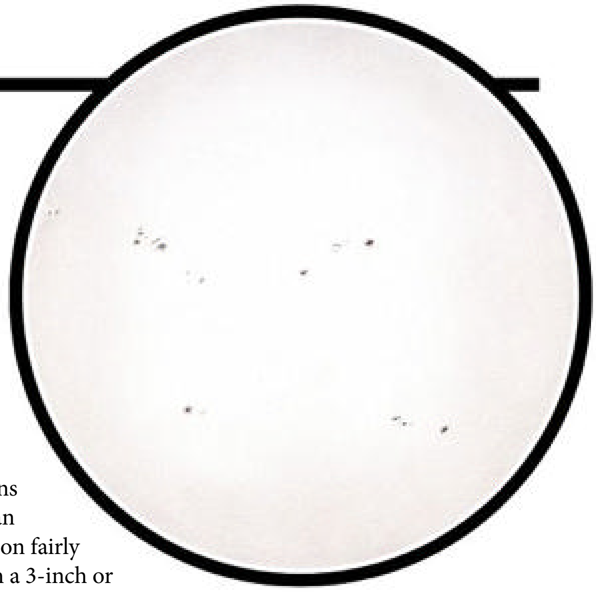
Filtered solar views

With the range of filters and telescopes available for solar observing these days, we have never had a better opportunity to safely observe the Sun from the comfort of our backyards. Amateur astronomers can now do that in two ways: Observe a wide swath of wavelengths that make up visible light, or restrict the view to a single wavelength, Hydrogen-alpha.

Viewing through a white-light (visual) filter makes a fine introduction to solar astronomy. It lets us observe the Sun's gaseous photosphere, commonly referred to as its "surface," and several of its features.

Sunspots, for example, show up well against the stark solar disk, becoming increasingly detailed at higher magnifications. They consist of umbrae, dark areas where the Sun's magnetic field is strongest, and they may include filamentary penumbrae, the not-quite-as-dark regions surrounding umbrae. Sunspots are cooler than their surroundings, causing them to appear dark by comparison.

Another feature, a facula, is a bright area of concentrated magnetic field lines. The best views occur when faculae lie against the darkened limb (edge). Something else to look at are granules, which are convective cells of plasma that resemble grains of rice. You can spot granulation fairly easily through a 3-inch or larger telescope under good seeing conditions.



The author made this solar sketch through a 4-inch refractor with a white-light filter. The magnification was 83x. She used a 6-inch drawn disk on white card stock, a felt-tipped black artist pen, a charcoal pencil, and a No. 2 pencil.

Our second option, narrow-band Hydrogen-alpha (Hα) filters, lets us observe the Sun's chromosphere, the layer just above our star's visible surface. Amateur astronomers use Hα filters that center on the red spectral line at 656.28 nanometers and let little else through.

Through this filter, the chromosphere is so alive with detail that sunspots lack the well-defined edges visible through a white-light filter. You will notice bright patches called "plage areas" — strong magnetic fields associated with faculae from the photosphere.

You also will spot prominences. These large gaseous features extend outward from the Sun's limb. When you spot a prominence silhouetted against the solar disk, it appears dark because the gas is cooler. Astronomers call those features "filaments." Solar flares, which are less common, appear suddenly bright and last up to a few hours.

Two common problems that come up while sketching the Sun through either filter are exaggerated size and misplacement of features. Oversizing results from an attempt to sketch highly detailed features in a limited space. Start with a larger circle as the solar disk; give yourself room to record your observations. And you can simplify the correct placement of solar features by using an imaginary grid for plotting.

When you sketch the Sun in Hα, maintaining dark adaption is essential — and it isn't easy in daylight. Blocking outside light around the eyepiece with a shield or dark cloth will improve your view and let you see faint detail that otherwise would be lost. Try sketching on black paper with a white pencil. This technique reduces glare, permitting your eyes to adapt more quickly when going from sketch to eyepiece.

Once you become comfortable with solar sketching, consider creating a sketch sequence of an erupting prominence or tracking an active region as it makes its way across the disk. Sketch sequences come to life through animation with software like *Photoshop* or *Gimp*. View an erupting prominence animation I created at http://wp.me/pY46X-LQ. Whichever filter you choose, with a little patience, you'll be on your way to a lifetime of solar sketching.

This Sun sketch shows features invisible through a white-light filter. The author observed with a 2.4-inch Hydrogen-alpha solar telescope with a double-stacked filter that yielded a bandpass of 0.45 angstroms and a magnification of 50x. She used a 6-inch drawn solar disk on black Strathmore Artagain paper, a white Conté crayon and pencil, a black oil pencil, and a charcoal pencil. The author rotated and flipped both sketches so that north is up and the preceding limb is to the right. BOTH IMAGES: ERIKA RIX

Astronomy 2013 Summer Sweepstakes OFFICIAL RULES

1. No Purchase Necessary. Official entry forms are bound in the June 2013, July 2013, and August 2013 issues of *Astronomy* magazine. The *Astronomy* 2013 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with your name, address, city, state or province, and zip or postal code to: The *Astronomy* 2013 Summer Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. Or enter online at www.Astronomy.com/sweepstakes by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for the 2013 Summer Sweepstakes will be July 19, 2013, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around September 17, 2013, for the following awards: One (1) Grand Prize consisting of a SkyProdigy 6 (retail value $999.00). One (1) First Prize consisting of an AstroMaster 70AZ (retail value $149.95). One (1) Second Prize consisting of a SkyMaster 15x70 Binoculars (retail value $89.95). One (1) Third Prize consisting of a Celestron FirstScope w/accessory kit (retail value $59.95). Ten (10) Fourth Prizes consisting of a one-year subscription to *Astronomy* magazine (retail value $42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 106,841. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* 2013 Summer Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Co. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late, or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release, and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected, or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

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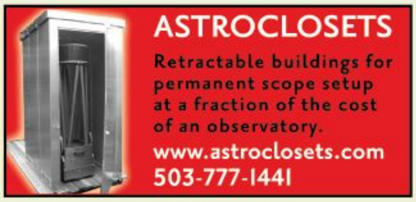

INDEX *of* ADVERTISERS

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READER GALLERY

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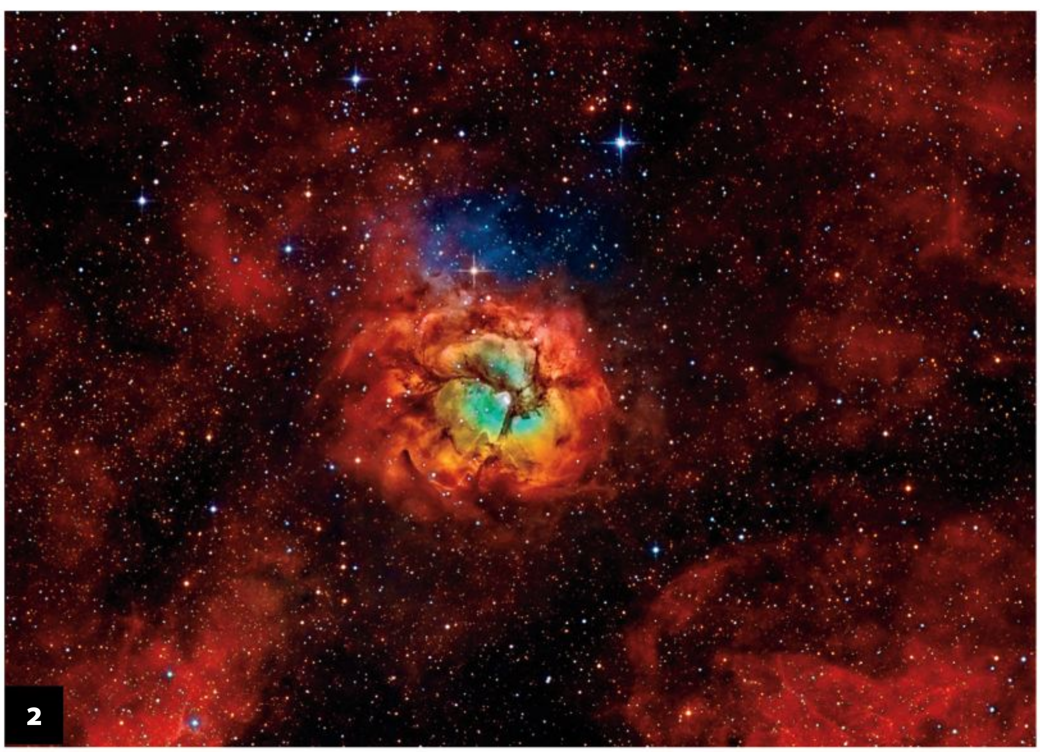
1. C/2011 L4 (PANSTARRS)
To the left of center, Comet PANSTARRS floats through the southern constellation Indus near an Iridium flare (upper right), which is a reflection from an Earth-orbiting satellite. The comet was easy to spot through binoculars but only appeared as a diffuse star to the naked eye. (Canon EOS 6D DSLR, 135mm lens at f/2.8, 10-second exposure, ISO 6400, taken February 11, 2013, at 4:25 A.M. local time, from Mercedes, Argentina) • ***Luis Argerich***



2

2. THE TRIFID NEBULA
M20 in Sagittarius makes a striking target to narrowband filters. This complex object combines emission, reflection, and dark nebulosity with a star cluster. (Hα and RGB: 16-inch Dream Telescopes astrograph at f/3.75 and an Apogee Alta U16M CCD camera; OIII and SII: 10-inch Boren-Simon PowerNewt at f/2.8 and an SBIG ST-8300M CCD camera; Hα/OIII/SII/RGB image with exposures of 30, 30, 30, 10, 10, and 10 minutes, respectively) • ***Kfir Simon***


3


4


5


6

3. NGC 2403
This spiral galaxy lies in the northern constellation Camelopardalis the Giraffe. Also known as Caldwell 7, it measures about 50,000 light-years across and floats some 8 million light-years from Earth. (14.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/8, Apogee Alta U16M CCD camera, LRGB image with exposures of 510, 220, 140, and 240 minutes, respectively)
• Mark Hanson

4. WIDE-FIELD IN ORION
This image shows a region in the constellation Orion from dark nebula LDN 1622 (upper left) to reflection nebula M78 (lower right). Barnard's Loop (Sh 2–276), a huge emission nebula, looms between the two objects. This image is the result of an incredible 38 hours of exposure time. (5.2-inch Takahashi TOA-130 refractor at f/6, SBIG STL-11000M CCD camera with AO-L adaptive optics, LRGB image with exposures of 20, 6, 6, and 6 hours, respectively)
• Alistair Symon

5. THE CHAMAELEON MOLECULAR CLOUD
This dark nebula is a star-forming region that resides in the far-southern constellation Chamaeleon. Most of the stars created here are young, low-mass T Tauri stars. This type of star doesn't generate energy through fusion but rather as a result of its gravitational collapse. (4-inch Takahashi FSQ-106ED refractor, SBIG STL-11000 CCD camera, LRGB image with exposures of 1,100, 200, 200, and 200 minutes, respectively)
• Yuri Beletsky

6. AURORA BOREALIS
The imager captured this beautiful curtain aurora's atmospheric glow as well as its reflection in the water beneath. Charged particles from the Sun interacting with our upper atmosphere create the beautiful colors. (Canon EOS 5D Mark II DSLR, Canon EF 24mm f/1.4L II USM lens set at f/1.6, ISO 800, 6-second exposure, taken January 14, 2013, at 8:33 P.M. local time, from Lapland, Finland ***• Jamie Cooper***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

ESO/DIGITIZED SKY SURVEY 2

A spectacular "hole in the sky"

This wide-field view of stars, gas, and dust in the southern constellation Scorpius shows a black cloud of interstellar dust known as Lupus 3. Consisting of fine particles of dust the size of those in cigarette smoke, Lupus 3 is about 600 light-years away and is gravitationally contracting into eventual protostars.

Young, massive, brilliantly hot stars like the ones that will form from Lupus 3 lie scattered across the right side of this image, which was created from images made for the second-generation Digitized Sky Survey. This view shows us our past. The Sun probably formed in a similar loose group of stars some 4.6 billion years ago.

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

August 2013: Saturn's great evening show

If you head outside as darkness falls, **Venus** will be the first point of light you see in the western sky. The beautiful beacon shines at magnitude –3.9 during August's first half and brightens slightly to magnitude –4.0 after midmonth. The brilliant planet lies more than 30° from the Sun and sets nearly three hours after our star. Venus moves eastward from Leo into Virgo during August and ends the month less than 10° below 1st-magnitude Spica, the Maiden's brightest star.

If you view Venus through a telescope, its phase will appear noticeably less than full. By the 31st, the planet's disk spans 15" and the Sun illuminates about three-quarters of the hemisphere that faces Earth. Remember this shape as you observe the planet in the months to come — our neighbor's apparent size will swell dramatically as its phase dwindles to a crescent by November.

Well above and a bit to the right of Venus stands **Saturn**, which remains an evening showpiece. The ringed planet continues its slow trek eastward through Virgo, ending the month on the Maiden's border with Libra the Balance. Saturn shines at magnitude 0.7, slightly brighter than Spica to its west.

Even a small telescope delivers stunning views of this distant world. The planet's disk measures 16" across at midmonth while the encircling rings span 37" and tilt 18° to our line of sight. The dark Cassini Division that separates the outer A ring from the brighter B ring shows up easily through 10-centimeter instruments in moments of good seeing. Also keep an eye out for Titan, the planet's biggest and brightest moon, and a handful of others that moderate apertures reveal.

The three remaining naked-eye planets all reside in the morning sky. **Jupiter** rises first and appears conspicuous in the northeast by the time twilight commences. It lies among the background stars of Gemini the Twins, a region that moves steadily farther from the Sun as the month progresses. By the 31st, the planet rises three hours before the Sun and shines brilliantly at magnitude –2.0 against a dark sky.

Early risers who target Jupiter with their telescopes can expect to see lots of detail in the giant world's atmosphere. The best views will come late in the month as Jupiter climbs higher and its equatorial diameter grows to 35". Its four bright moons — Io, Europa, Ganymede, and Callisto — are easy targets and show up even through binoculars if you hold them steady.

Mars follows close on Jupiter's heels as they both ascend in the predawn sky. The Red Planet appears much less conspicuous than its sibling, however, glowing some 25 times dimmer at magnitude 1.6. You should be able to identify Mars from its distinct reddish color. A telescope reveals a bland disk just 4" across. It won't appear appreciably bigger until 2014.

You should be able to spot **Mercury** to the lower right of Mars in early August. On the 1st, the innermost planet lies some 5° above the horizon 45 minutes before sunrise. Despite its low altitude, Mercury shows up because it shines brightly at magnitude –0.1. Use binoculars if you can't find it quickly with naked eyes. A telescope reveals a halflit disk that spans 7". Mercury disappears in the twilight glow before midmonth; it passes behind the Sun from our perspective August 24.

The starry sky

The wonderful constellation Scorpius the Scorpion passes nearly overhead as night falls in August. It stands out in part because it holds so many bright stars in such a distinctive shape. The most obvious pattern is a looping curve that forms the Scorpion's tail at the constellation's southern end.

The 1st-magnitude star Antares marks the Scorpion's heart. The star's name means "rival of Mars," an obvious moniker once you see the objects' similar colors. The ruddy hue of the Scorpion's heart stands out on these August evenings.

Antares is a red supergiant star with a mass some 15 to 18 times that of the Sun and a luminosity that may reach as high as 90,000 Suns. Such a star makes a good candidate for becoming a supernova. People often ask me whether the stars we see in the sky are still there, based on their great distances from Earth and the long time it takes their light to reach our planet. It's almost certain that all of the naked-eye stars we see are still around, but Antares could be the exception. At a distance of approximately 550 light-years, it could have ended its life with a supernova explosion anytime after about the year 1460 and we would not know about it yet.

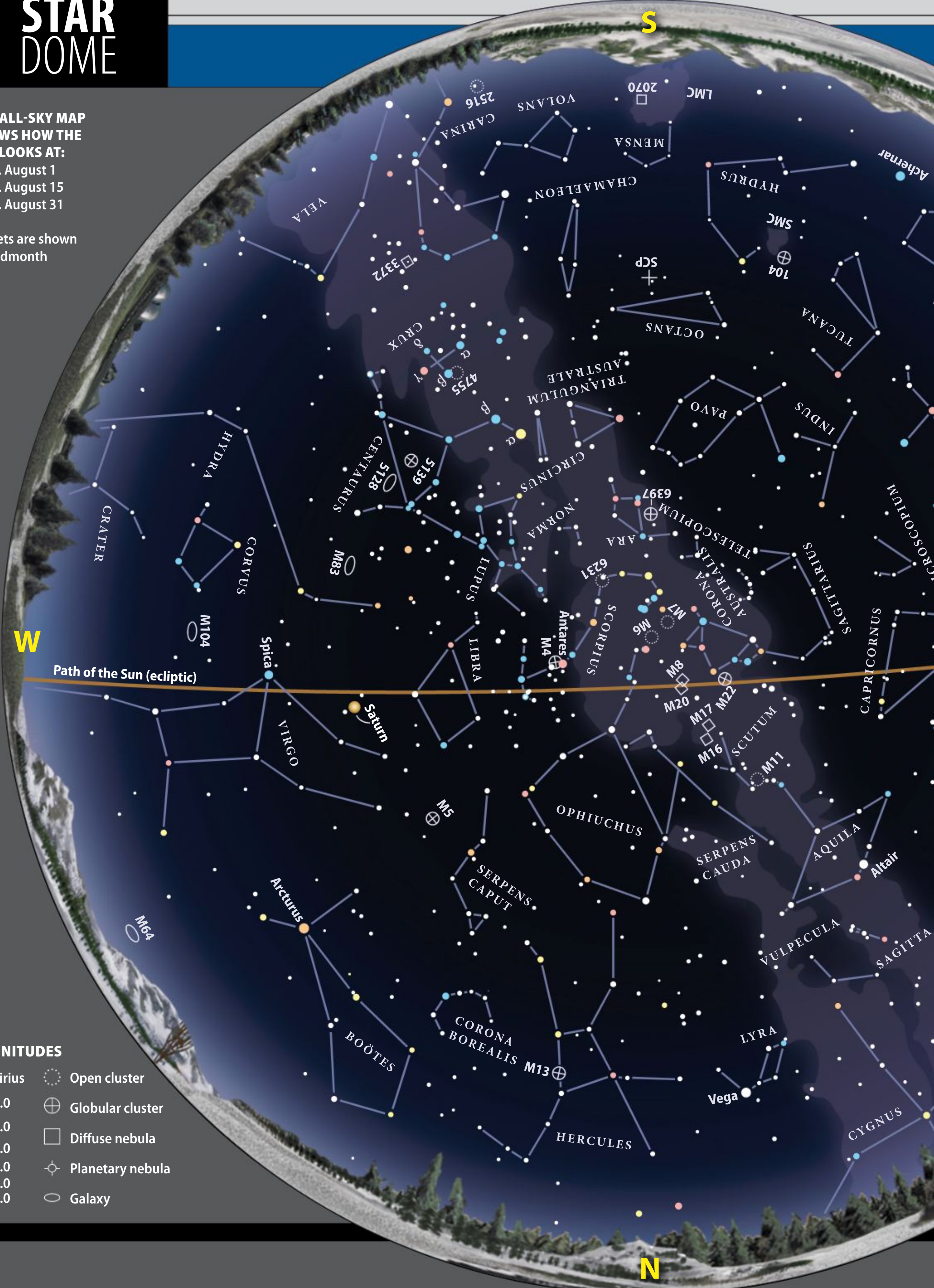
Antares has a companion star that's notoriously difficult to see. This 5th-magnitude attendant lies only 3" west of the primary star. Austrian astronomer Johann Bürg discovered the companion in April 1819 during a lunar occultation when it appeared from behind the Moon's limb before Antares. The fainter star would be a naked-eye object if it were by itself in a dark sky, but its proximity to the brilliant red supergiant makes it invisible in telescopes smaller than 10cm aperture.

Although the companion is a hot star that should have a blue-white color, observers often report it as green. Astronomers think this arises from a contrast effect with the red color of the primary. One of the finest views I've had of this pair came one night in the 1990s through the 23cm Oddie Telescope at Mount Stromlo Observatory in Australia, and I must admit the companion appeared vivid green to me.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
9 P.M. August 1
8 P.M. August 15
7 P.M. August 31

Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

AUGUST 2013

Calendar of events

3 The Moon is at apogee (405,832 kilometers from Earth), 8h53m UT

The Moon passes 4° south of Jupiter, 22h UT

4 Asteroid Juno is at opposition, 1h UT

The Moon passes 5° south of Mars, 11h UT

5 Mercury passes 7° south of Pollux, 3h UT

The Moon passes 4° south of Mercury, 9h UT

6 Asteroid Vesta is in conjunction with the Sun, 4h UT

New Moon occurs at 21h51m UT

10 The Moon passes 5° south of Venus, 2h UT

12 The Moon passes 0.6° north of Spica, 9h UT

13 The Moon passes 3° south of Saturn, 8h UT

14 First Quarter Moon occurs at 10h56m UT

16 Asteroid Iris is at opposition, 17h UT

18 Asteroid Ceres is in conjunction with the Sun, 1h UT

19 The Moon is at perigee (362,264 kilometers from Earth), 1h26m UT

Mars passes 6° south of Pollux, 12h UT

21 Full Moon occurs at 1h45m UT

The Moon passes 6° north of Neptune, 15h UT

24 The Moon passes 3° north of Uranus, 7h UT

Mercury is in superior conjunction, 21h UT

27 Neptune is at opposition, 2h UT

28 Last Quarter Moon occurs at 9h35m UT

30 The Moon is at apogee (404,881 kilometers from Earth), 23h46m UT

31 The Moon passes 4° south of Jupiter, 17h UT